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**RELATIONSHIPS BETWEEN
MOBILITY, SUSTAINABILITY,
AND FIREPOWER**

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Executive Summary

RELATIONSHIPS BETWEEN MOBILITY, SUSTAINABILITY, AND FIREPOWER

Current world events are causing wide-ranging reviews of our national security strategy, and those reviews require an assessment of the forces needed to support the strategy alternatives. The reviews originally focused on the changing nature of the threat to peace in Europe, but with the massive operations currently underway in the Middle East, the future is even more complicated. Although decisions may be deferred until the current crisis has been resolved, we will eventually have to settle on the shape and size of our active and reserve forces for the next decade and beyond.

In part, any decisions addressing force structure, particularly the mix of heavy versus light forces, must consider the mobility of that force, that is both the deployment requirements of the forces under consideration and the available strategic mobility capabilities. A planning dilemma is caused because the forces that potentially bring the most combat capability, or firepower, to bear generally require the greatest lift and are, therefore, the most difficult to deploy. With the reduced threat of a general conventional war on the European continent, the debate has begun again between those advocating the restructuring of our forces into lighter, more easily deployable configurations and those arguing that heavier forces not only bring more firepower but are more survivable in future engagements no matter where they may be fought. Establishing the correct mix between the different types of forces is not a simple problem, particularly as we reduce our force levels. The current Middle East war will surely enrich the debate.

Much has been written recently about how long it takes to deliver a force by sealift, in comparison with airlift. The reality is that for virtually all ground combat forces other than light divisions, closing a combat force to most regions of the world will likely involve sealift unless we have pre-positioned massive amounts of materiel. The Marine Corps Maritime Prepositioned Ships are an example of what can be achieved with pre-positioning afloat. If the deployed force is to sustain its effective firepower, it must include support. When support is included in the movement

requirement, the need for sealift is even more pronounced. The deployment time differences between light and heavy combat forces are substantially reduced when the sustaining support forces are also considered.

To maintain a balanced deployment, *early* lift should be allocated to both combat and support units; when it is, the closure time differences between light and heavy forces are further decreased. Competition for lift thus does not merely involve tradeoffs between tactical fighter wings and Army divisions or between Army brigades and Marine Expeditionary Brigades, but it also involves tradeoffs between those types of units and the support they require.

With regard to the relationship between mobility and firepower when the additional dynamic of force sustainability is considered, we reach the following conclusions:

- Combat capability, or firepower, is a better measure of force build-up than numbers of units (brigades, divisions, etc.) delivered to an objective area.
- When nondivisional support units are included with divisional units, the firepower build-up differences between light and heavy ground forces are diminished. Thus, as a general rule, it may be worthwhile to accept the marginally slower deployment of a far more combat capable and sustainable force. If so, the potential contributions of light versus heavy forces should be reassessed.
- Allocating our most capable strategic lift and highest priorities to the combat units results in a force that is critically unsustainable for some period of time. For example, assigning an airborne division a high priority for airlift and the active brigades of a mechanized division and/or an air assault division first claim to the Military Sealift Command's fast sealift ships ensures these units will arrive in an objective area well ahead of the support forces necessary to sustain them. The combat units may face a period of unacceptable risk of failure between their arrival and the establishment of an adequate logistics support capability.
- Firepower values and unit counts are not sufficient for assessing the military capability of a deploying force without a corresponding assessment of force sustainability.
- An unsustainable force may be deployed for legitimate reasons, but the associated risks of failure in combat should be recognized.

We recommend the following actions be taken:

- **DoD offices with force structure responsibility should recognize the relationship between force deployability, sustainability, and firepower when force structure changes are proposed. Specifically, those offices should include support force requirements in the force costing process and propose a measure of effectiveness that considers the relative costs of deploying sustainable fighting forces with variable firepower values.**
- **The Joint Staff should develop a methodology to assess the dynamic relationship between deployability, sustainability, and firepower in the operational planning process and specifically in the development of time-phased force deployment lists for various contingencies and plans.**
- **Recognizing that the *Operation Desert Shield* deployment will be fully documented and studied, the deployment lessons learned should be examined in light of the issues we raise in this report on force sequencing, sustainment, and risk. They can be much better understood through an analysis of actual deployment data rather than simulated data.**
- **Pre-positioning of unit equipment – ashore or afloat – may be viable options for speeding deployment of heavy Army units; they should be explored as an integral part of force structure decisions.**

In summary, this paper shows that the rapid deployability advantage of light forces disappears when the size of the deploying force exceeds airlift capability. It also shows that the deployment advantage – when it exists – of light forces is diminished when logistical support requirements are included in the movement requirement. Furthermore, when combat capability, or firepower, is considered, the advantage of the light forces may disappear entirely. Recognition of these factors should be central in force structure decisions, specifically in making the choices between heavy and light forces.

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CHAPTER 1

INTRODUCTION

BACKGROUND

Developing, equipping, and fielding combat forces is a complicated, lengthy, evolutionary process involving military doctrine, future threat assessments, budgetary considerations, technological thresholds, congressional oversight, and many other factors. In the past, as new items of equipment were developed, deployment considerations received lower priority than performance and survivability considerations. Thus, when individual items are aggregated into units, we have very capable units that are difficult to move. (The light infantry division is an exception.)

Planning for the deployment of various size forces is a complex process. Once the strategic mobility capability has been determined, the allocation of available lift, during both planning and execution, is an even more difficult process, subject to many considerations. Widely different Service requirements, the supported Commander in Chief priorities, the opposing threat expected to be encountered, the availability and type of lift assets, and the number and kinds of units already deployed within the region are just a few of the considerations that affect the decision to move specific units by either airlift or sealift, at a particular point in a deployment sequence. An important question is how to deploy the most effective and sustainable combat power early with the available airlift and sealift, and the answer lies in understanding the dynamic nature of the relationships between mobility, sustainability, and firepower. (Appendix A defines in detail those three elements.)

PURPOSE

The dramatic events occurring around the world and the reduced emphasis on the European theater have caused planners in and out of the DoD to once again raise the issue of how to increase the ability to deploy our forces. In this paper, we discuss the differences between the types of combat units in terms of their firepower and the strategic lift needed to deploy them (mobility). We added one more complicating variable, sustainability, which we have defined as the additional tonnage that must

be deployed with the combat force to give it the capability for continuous operations. That additional tonnage includes the weight of support force units and consumable supplies. Since different types of units have different sustainability requirements, our analysis links the three variables and determines the effect that the sustainment variable has on the basic relationship between firepower and mobility.

ESSENTIAL ELEMENTS

We began this study in March 1990, focusing coincidentally on the Middle East in an attempt to sharpen the focus on force structure issues by exploring some of the relationships between force structure, measured in terms of firepower and the required lift associated with that power. We added a dimension – sustainability – which we defined as the additional tonnage needed to be deployed with the combat force to give it the capability to operate. This tonnage includes the unit equipment weight of the combat support and combat service support units deploying with a combat force, as well as the consumable supplies necessary to sustain the force. We believe that too little attention has been given to understanding the relationship between force sustainability and changes in force composition. Some relationships are explored in detail in Chapter 2. Each of the elements is affected by, and in turn affects, the other. Additionally, each of the elements consists of a wide range of conflicting variables.

In conducting this analysis, we explored the following:

- The lift required for various types of Army divisions with and without nondivisional support and the comparative deployment times by air and sea under varying conditions
- The lift required for Marine Expeditionary Brigades and Air Force Tactical Fighter Squadrons and their support
- The impact that support force deployments and consumable stocks have on combat force deployments
- The firepower scores, using various scoring systems, for Army and Marine Corps combat units as they relate to the mobility assets required to deploy them
- The tradeoffs available between deployability, sustainability, and firepower.

Many of the data elements required for these types of analyses are supported by mobility simulations. In this analysis, the development of data was less important

than in similar studies for several reasons. First, we treated many of the principal considerations as variables to be explored, rather than as constants. Second, much of the data we used are the same as those used by OSD and the Joint Staff in their mobility studies. Finally, our goal was to compare differences in deployment sequences, modes, and sustainability levels for different types of units rather than to develop specific requirements or perform capability assessments. For those reasons, we do not focus on data development. However, some data elements and related subjects require an explanation in order to better understand the results; we describe them briefly in the following paragraphs.

Assumptions

In this analysis, conclusions are dependent on our assumptions on the availability of strategic lift, and particularly on the modes (air or sea) used for the movement of specific units. Changes in those assumptions have the potential for changing the conclusions. For that reason, rather than accepting many of the commonly used mobility assumptions, we analyzed the effect of mode changes and assumptions on the availability of airlift and sealift and describe the resulting effect on unit and force deployments. We make many other assumptions throughout the analysis, but they are more appropriately described in the pertinent sections.

Force Sequence

Another important variable is unit sequence within a force. In the initial part of our analysis, we showed the effect of mode changes on closures by analyzing the movement of individual-type combat units with their support packages. However, in order to be fair in comparing the effects of variables on firepower build-up rates, we used an aggregate force of many different size units and support requirements in the second part of the analysis. Only by allowing units to compete with their support units for lift were we able to determine the range of firepower values within the same force. The Services-provided required delivery dates (RDDs) were used as the start point of the analysis, but we altered the RDDs when necessary to change firepower buildup or sustainability ratios.

Deployment Origins, Destinations, and Routing

We assumed a force deployment from continental United States to Saudi Arabia. Given that units originated at many points within the United States, the

average airlift distance to the principal destination airfields was 6,600 n.mi. The sailing distance from the U.S. East Coast ports to the Saudi Arabian Persian Gulf ports averaged 12,000 n.mi., assuming the Suez Canal was closed. In the type unit examples, we deployed a light division from the West Coast (the most likely point of origin). The distance in that case was 8,900 n.mi. by air and 11,000 n.mi. by sea. We also compare the air-versus-sea deployments of a heavy division if the Suez Canal is open. In that instance, the airlift advantage over sealift is reduced because of the shorter sea distance (8,000 vice 12,000 n.mi.).

Combat Forces

In our initial analysis, we used four different types of Army divisions to illustrate the deployment time differences among them. We considered an airborne division, a heavy division (mechanized), a light division, and an air assault division. In the second part of our analysis, we assessed the following combination of unit types comprising a notional force:

- 1 airborne division
- 1 air assault division
- 2 mechanized divisions (2 brigades each)
- 1 armored cavalry regiment
- 3 Marine Expeditionary Brigades
- 15 tactical fighter squadrons.

Support Forces

In the initial part of the analysis, we developed support force packages for the different types of Army units from existing Service-developed databases by taking a mix of support units with a ton of support unit equipment for every ton of combat unit equipment. That 1:1 unit weight ratio represents the minimal level of support necessary to sustain combat force operations for a limited time. For the second part of our analysis, which focused on deploying a force rather than individual types of combat units, we used a different support force mix. Previous analysis at the Logistics Management Institute (LMI) indicated that the relationship between combat force and support force unit weights is highly variable and depends on the size of the force, the environment into which it is deploying, the amount of available

forward deployed or pre-positioned support, etc. The data we examined showed support-to-combat tonnage ratios ranging from less than 1:1 to more than 3:1. The Army database for a contingency similar to our problem had a support-to-combat weight ratio of 2:1. We elected to use that 2:1 ratio in our notional force. We made adjustments where necessary to maintain consistency in movement characteristics (oversize, outsize, and bulk), in addition to the total weight relationship.

Support force data for Marine Expeditionary Brigades were obtained directly from Marine Corps program objective memorandum submissions, identified as either part of the pre-positioned equipment or as the assault follow-on echelon. Thus, we did not have to use ratios for the Marine Corps units as we did for the Army units.

We developed support ratios for Air Force tactical fighter squadrons from existing database ratios between numbers of aircraft and support unit weight required per aircraft.

Time Line

Graphical illustrations generally show a build-up of tonnage, units, or firepower over time. We chose not to make an assumption about the start of hostilities in relation to the start of movements from home station to air and sea ports of embarkation (Day 0) because that assumption has the potential to change significantly the mobility solutions we analyzed. For example, Marine Corps Maritime Prepositioned Ship (MPS) brigades can only be offloaded in a benign environment. If we assumed that combat operations had begun, we would have had to assign a different destination to these forces. We viewed these deployments as deterrent force deployments, with hostilities being deferred until after the deployment was completed. Even under that assumption, we could still assume that hostilities would start at a different point along the time line on each of the graphs and could examine the data as of that time.

Model

The MINOTAUR model, a personal computer (PC)-based mobility model developed for the Office of the Assistant Secretary of Defense (Program Analysis and Evaluation [OASD(PA&E)]), which incorporates many of the same features as the mainframe MIDAS model used by OSD and the Joint Staff, was used for the mobility simulations. While the PC-based model cannot develop the same level of detailed

reports that MIDAS can, it can produce major unit closure results that are consistent with the more detailed model. Since major unit closures were the primary measures of effectiveness (MOEs) we analyzed, the disadvantage of having less-detailed output data from MINOTAUR was more than offset by the advantage of speed in performing multiple simulations.

Mobility Assets

The airlift and sealift assets used in this analysis varied under different sets of assumptions. The starting point was the Military Airlift Command (MAC) fleet of strategic airlifters available in 1990; the Civil Reserve Air Fleet aircraft; the Military Sealift Command (MSC) fleet of Government-owned or Government-chartered active ships; the Ready Reserve Force (RRF) fleet of Government-owned reserve ships maintained in either 5-, 10-, or 20-day readiness postures; and the U.S. flag dry cargo commercial fleet operating in 1990.

BALANCED VERSUS UNBALANCED FORCES

A land combat force could be deployed not to engage in combat but as a show of force to deter war; in such a case, the question of sustainability could be of secondary importance. In recognition of the risks inherent in such a deployment, we demonstrated the difference in firepower build-up possible if the goal were to achieve maximum firepower in the shortest time without the support force or consumable supplies slowing down the combat force deployment. We compared these results as the differences in firepower potential between deploying a balanced and an unbalanced force.

RELATIONSHIP BETWEEN THIS ANALYSIS AND OPERATION DESERT SHIELD DEPLOYMENTS

Coincidentally, we began this analysis in March 1990, 5 months before the August 1990 Persian Gulf crisis erupted. While the simulated deployments we describe are similar to those actually conducted, these hypothetical simulations should not be compared with the actual deployments without recognizing that many key factors and assumptions are different. For example, in our base case, we assumed a 75 percent allocation of available airlift to our deployment while the actual number was higher; we supplemented the MAC airfleet with charter aircraft, while CRAF Stage I was activated early in *Operation Desert Shield*; we assumed the RRF ships

began to load on their planned 5-, 10-, and 20-day availability schedules, but their availability at the berth generally was somewhat slower for many reasons; we assumed the Suez Canal was closed, but it was open for the actual deployment. When all the differences between the simulation and the actual deployment are thoroughly considered, useful comparisons can be made to put these hypothetical relationships into sharper focus. We certainly believe the issues we raise have been reinforced by the actual deployment.

CLASSIFICATION

Much of the data necessary to perform such simulations as these originate in classified sources. To give this report the widest possible dissemination, however, we chose to hold its content to the unclassified level. We purposely avoided specific references or data descriptions that would have required a change in classification. As a result, some discussions may not be as detailed as possible and other topics are not even addressed.

CHAPTER 2

THE PROBLEM ILLUSTRATED

Why perform this analysis? Development of time-phased force deployment data is a complicated process that begins with a list of available units. Our analysis shows relationships that will help force structure planners develop the list of units for the future. Our hypothesis was that linkages exist among all the variables that should be considered in force structure decisions (for our purposes, firepower represents force structure). Unless firepower can be delivered to the point at which it is needed, and then sustained, it is of little value. Figure 2-1 is the conceptual framework of our analysis.

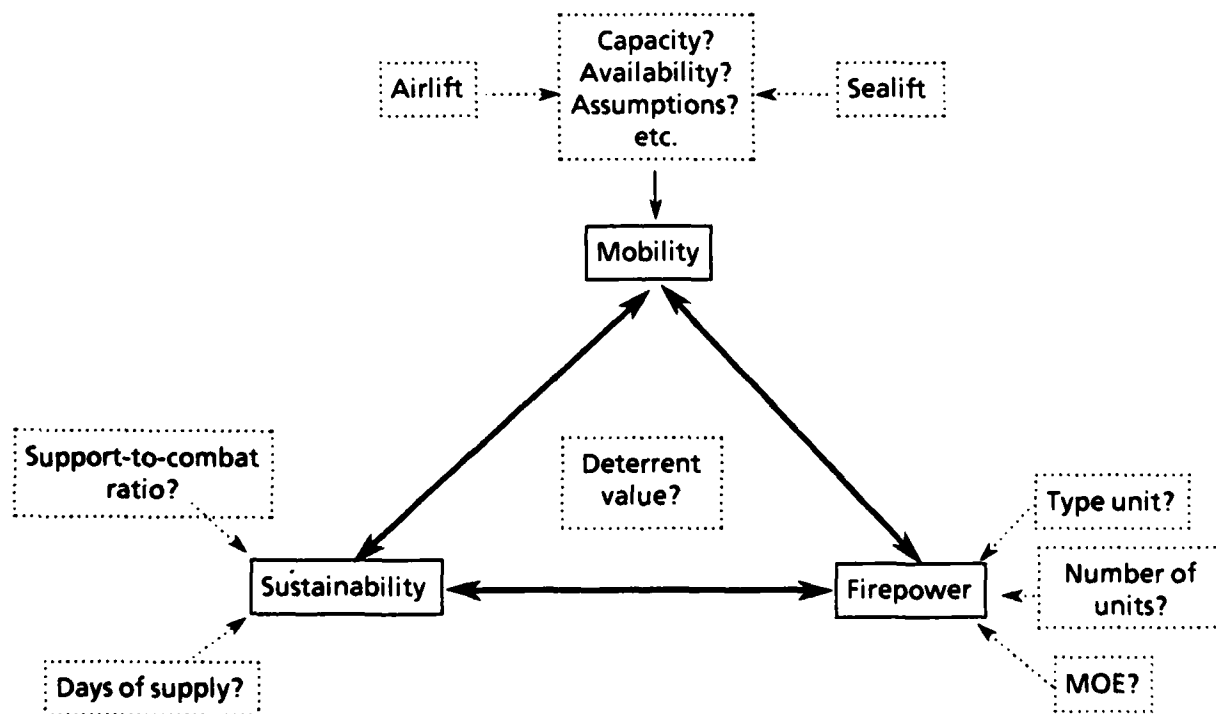


FIG. 2-1. MOBILITY, SUSTAINABILITY, AND FIREPOWER LINKS

We know that a three-way relationship exists between each of the major elements of our study. In this study, we quantify the effect of the relationships on each other. In this chapter, we show only that differences in possible solutions exist

and that they are potentially significant. We illustrate possible differences in a series of charts; the data in those charts are not labeled because in this discussion the details are irrelevant. The data differences shown are explained in detail in Appendix B.

Figure 2-2 shows the notional division equivalent build-up curves for a base case and three different excursions. Some build-ups are clearly more favorable than others, using numbers of divisions deployed as the measure of effectiveness. However, if we change the measure of effectiveness to firepower, as shown in Figure 2-3, we get qualitatively different build-up curves for the four cases.

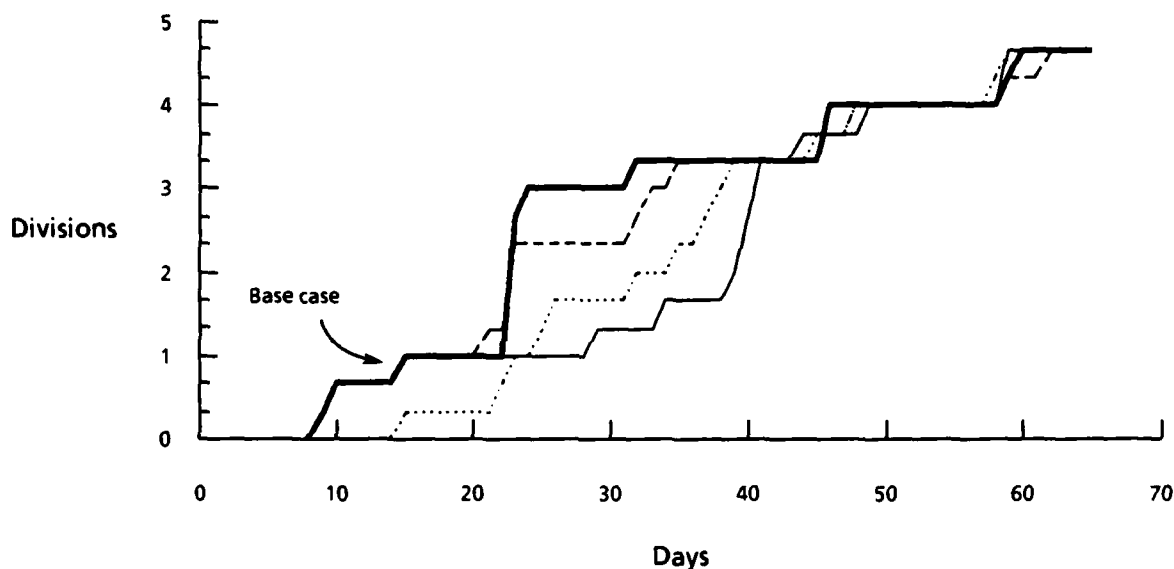


FIG. 2-2. DIVISIONAL BUILD-UP COMPARISONS
(Brigade increments)

Before we can decide which of the four cases represents the preferred deployment, however, we must consider another factor, sustainability. Figure 2-4 shows one measure of force sustainability, the support-to-combat ratio, in terms of tons delivered, for each of the four cases shown in Figures 2-2 and 2-3. Two cases stand out; one has a spike in the ratio that approaches 6:1 at Day 31, and the other has a ratio that approaches 0.1:1 at Day 23. From the logistics perspective, neither solution is acceptable. The ratios seen in the 0.1:1 case reflect a case in which combat unit tonnages receive priority for lift assets over support; in that case, the force is not

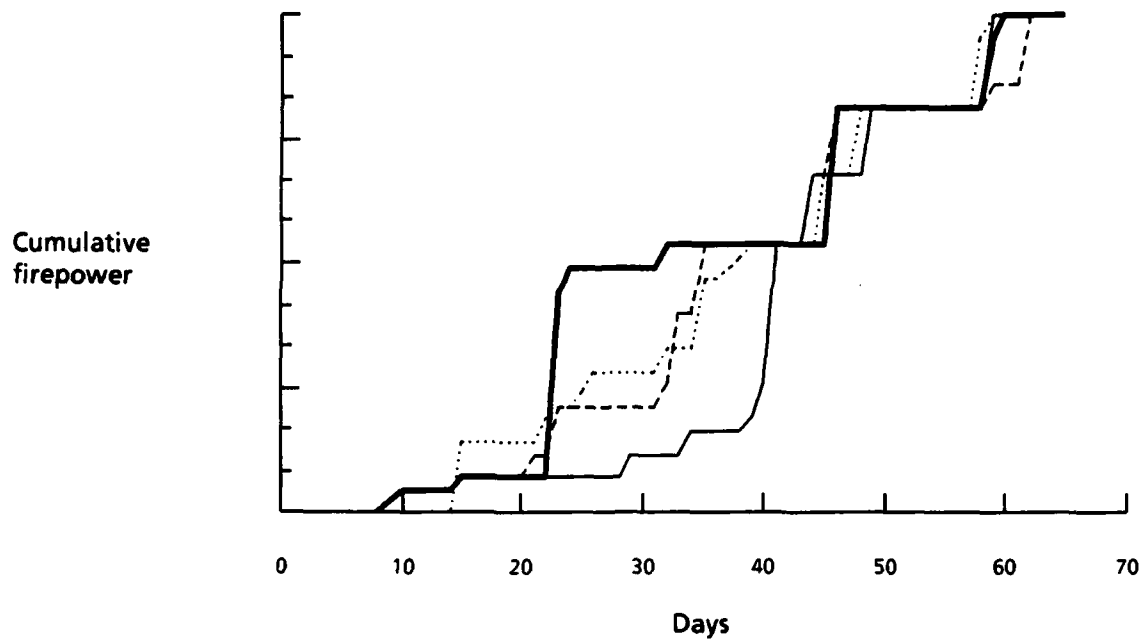


FIG. 2-3. DIVISIONAL BUILD-UP COMPARISONS
(Relative firepower)

sustainable. In the 6:1 case, the support tonnage is dramatically improved but the combat force is deployed much slower (see Figures 2-2 and 2-3).

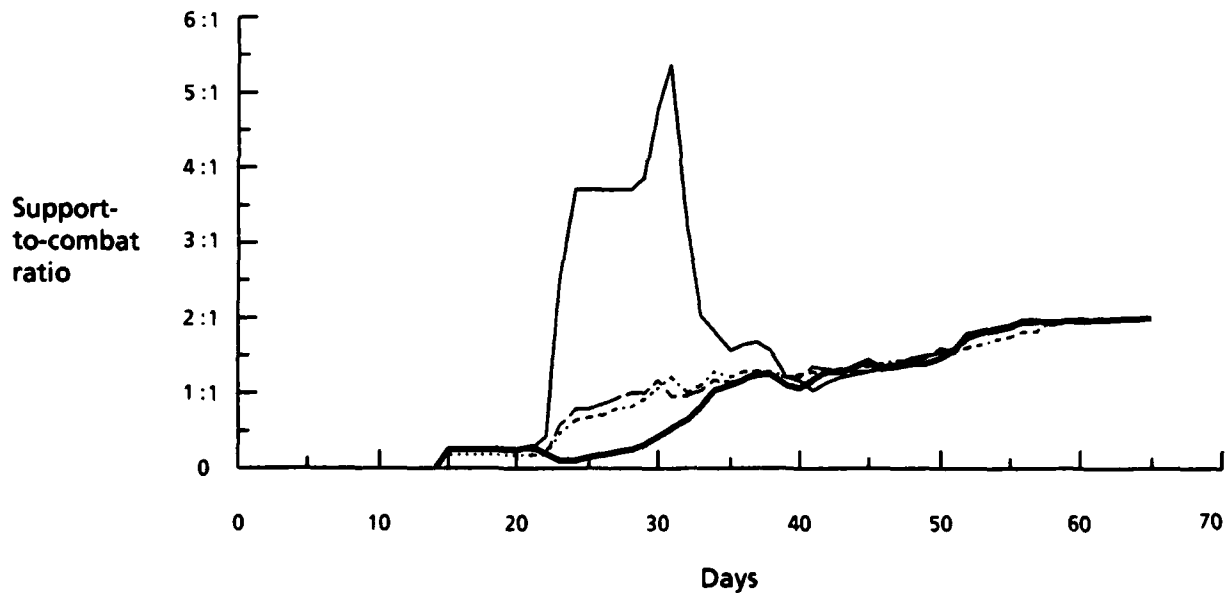


FIG. 2-4. SUPPORT-TO-COMBAT RATIO COMPARISON
(Unit equipment tons delivered)

From a sustainability perspective, either of the cases in the middle is an acceptable solution. The judgment as to which of these two is better must be made by combining the combat force build-up with the support-to-combat ratio. The only remaining question is the measure of effectiveness to be used. Figure 2-2, showing numbers of divisions at brigade level increments, favors one solution, while Figure 2-3, showing firepower build-up, favors the other.

No decision could be made on force selection or sequencing based on these considerations alone. Other factors that must be weighed by decision makers in determining which units to deploy and when to deploy them in relation to each other include operational considerations, the threat, warning time, unit readiness, political environment, and others. However, since decisions will soon be made as to the future composition of U.S. forces, we have devoted the remainder of this report to exploring some of the many factors and relationships that should be part of that force restructuring. Our examples, described briefly in this chapter, could lead to the selection of one particular case as the best combination of lift, sustainability, and combat power. It is this analytical process that we believe worthwhile and that we describe in more detail in the appendices to this paper.

CHAPTER 3

OBSERVATIONS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter offers a brief summary of the report. In many instances, points are made on the basis of comparisons and state what may appear to be obvious, yet the data provide qualitative differences.

OBSERVATIONS

In the course of our study, we made the following observations:

- Light forces deploy more quickly by air than do heavy forces. Although this observation seems obvious, it has to be qualified because it is only true under a given set of conditions. Clearly, if airlift were unlimited and no constraints were imposed on the capacities of the airfields used for either departure or arrival, the weight to be moved would be irrelevant. Since airlift and airfield capacities are limited, the lighter the force, the more quickly it can be deployed.
- Including support requirements reduces the airlift advantage inherent in light forces. No combat unit can be deployed and expected to fight for any period of time without sustaining supplies and support units. Yet too often, when comparisons are made between the deployability of light and heavy forces, the assumption is that the same relative advantage seen with the combat force is extended to the support. That is not the case. Many support functions must be performed regardless of the force composition. The more important point is that when support requirements are considered, the additional weight to be deployed reduces the ability to deploy light forces solely by air.
- As total movement requirements increase, a point is eventually reached at which sealift will deliver the last ton as quickly as airlift. Whether the increase in movement requirements is attributable to a heavier combat force or to the inclusion of the support requirement, with a fixed airlift capacity, sealift ultimately becomes the mode of choice. The current debate over how to reduce the weight of deploying forces to enable more rapid deployments by air is relevant only at the lowest end of the movement requirement spectrum, reflecting either the level of conflict, the size of the force, or the type of units in the force. While airlift will always play a critical role in delivering high priority cargo early, sealift is needed to complete the deployment of any force larger than one light Army division. Once the

deployment problem becomes a sealift problem, the weight to be moved is less important than the early availability of capable ships.

- Many assumptions are necessary to calculate the available airlift capacity; the calculation of sealift capacity, while still based on some assumptions, is less sensitive than airlift. This is an important point. The calculations which attempt to demonstrate the trade-off between air and sea deployments as a function of requirements are based on assumptions affecting capabilities. The assumptions affecting airlift produce a much wider range of possible fleet capacities than do those affecting sealift. The result is that, once again, the circumstances in which airlift will consistently outdeliver sealift are very limited.
- Although no easy ways are available to measure force sustainability, it is an essential element of any force deployability analysis. We have many examples of deploying combat forces without adequate support structure. Measuring sustainability is difficult, particularly where it is affected by widely variable, and in some cases, uncertain factors such as rates of consumption, assumed levels of host nation support, and length of the in-country line of communication. However, we must assess it, and often we fail to give it sufficient thought in building force deployment sequences. The result, then, in either our planning, exercises, or actual deployments, is a rapid build-up of combat forces with an agonizingly slow build-up of the support forces required to sustain combat. It is a pattern we have seen repeated in recent years; yet because of our inability to articulate support requirements, sufficient support forces are deployed only when the need becomes painfully evident. Our analysis describes various measures that can be used to determine whether a deployment sequence is sufficiently balanced to sustain the combat force if it must fight before the deployment is completed.
- Firepower is a valid qualitative measure of the force being deployed. Matching firepower with the lift required to deploy it and sustain it presents deployment sequence and mode selection options that are different than we routinely consider. Ample evidence exists to suggest that because the building of time-phased force deployment lists (TPFDL) is a complicated process, we have not always given consideration to the quality of the force we deploy with scarce, premium mobility assets. Firepower is one measure of that quality. In our examples, we show that the same amount of lift applied to different units in different sequences results in considerable differences in deployed force capability. Specifically, being able to deploy the 82nd Airborne Division quickly to the other side of the world may not be to our advantage if that division is neither sustainable nor a match for the opposing force. We recognize that in most cases, decisions to make such deployments are the result of political considerations. Our point is that

other, less risky deployment solutions may be available to convey essentially the same political message.

CONCLUSIONS

After considering all the data developed in this study, we drew the following conclusions:

- *Firepower is a better measure of force build-up than numbers of units (brigades, divisions, etc.) delivered to an objective area.*
- *When nondivisional support units are included with divisional units, the firepower build-up differences between light and heavy ground forces are diminished. It was apparent, for some types of units, that firepower differences are not directly proportional to the time necessary to deploy them. We may find it worthwhile to accept the marginally slower deployment of a far more combat capable and sustainable force. In this context, light forces do not compare favorably with heavy forces. In some scenarios light forces can be effectively employed, but considering the more probable threats we face outside the European theater, reducing the number of heavy forces in our structure because they are more difficult to deploy may not be the right solution.*
- *Allocating our most capable strategic lift and highest priorities to the combat force results in a force that is critically unsustainable for some period of time. For example, assigning the airborne division a high priority for airlift and the active brigades of a mechanized division and/or the air assault division first claim to the SL-7s (fast sealift ships maintained in a high state of readiness by MSC), ensures the arrival of these units in an objective area well ahead of the support forces necessary to sustain them. The risk of failure in the period between the arrival of the first combat units and the establishment of an adequate logistics support capability may be unacceptably high.*
- *Neither firepower values nor unit counts are useful for comparing our force closure combinations without a corresponding comparison of force sustainability.*
- *While we may have legitimate reasons for deploying an unbalanced (unsustainable) force, the associated risks of failure in combat can be very high.*

RECOMMENDATIONS

Based on our observations and conclusions, we recommend the following actions be taken:

- *DoD offices with force structure responsibility should recognize the relationship between force deployability, sustainability, and firepower when force structure changes are proposed. Specifically, DoD should include support force requirements in the costing process and should propose a measure of effectiveness that considers the relative costs of deploying sustainable fighting forces with variable firepower values.*
- *The Joint Staff should explicitly recognize the dynamic relationships between deployability, sustainability, and firepower in the operational planning process, specifically in the development of TPFDL for various contingencies and plans.*
- *Recognizing that the 1990 Middle East deployment will be carefully documented and studied, the lessons learned should be considered in light of the issues raised in this report. The issues regarding force sequencing, sustainment, and risk can be much better understood by an analysis of actual deployment data rather than simulated data.*
- *Pre-positioning of unit equipment — ashore or afloat — may be viable options for speeding deployment of heavy Army units; they should be explored as an integral part of force structure decisions.*

APPENDIX A

MOBILITY, SUSTAINABILITY, AND FIREPOWER DEFINED

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MOBILITY, SUSTAINABILITY, AND FIREPOWER DEFINED

This appendix describes in greater detail the three elements of analysis for which we established a linkage. All three elements are complex, and we make no attempt to describe comprehensively every aspect of each. Instead, we merely explain, in very basic terms, some of the variables that interact to produce different results. The analysis shown in Appendix B is based on the discussion in this appendix, as are the observations and conclusions described in Chapter 3 of the main text.

MOBILITY

The process of building force arrival schedules such as those seen in Chapter 2 requires an understanding of the differences among various kinds of units and the time required to deploy them. This section addresses those issues in two parts. First, we compare possible closure time differences for various types of Army divisions deploying either with or without support and we show how the different requirements affect the comparison between airlift and sealift deployments. These comparisons are very simplistic, having been accomplished with no competition for the available lift resources.

The interactions between varying requirements and mode changes become more important in the force deployment comparisons rather than type unit comparisons, and they are also described. However, since specific units are far less visible in a force, they are shown as individual movements first to illustrate a fundamental deployment relationship; both airlift and sealift closure times are a function of the size of the requirement versus the mobility assets available. Through this discussion, it is easier to understand the set of conditions at which airlift and sealift compare favorably.

The discussion also explores some of the critical assumptions necessary to size the mobility assets and shows the effect the assumptions have on force build-up. The section closes with a discussion of other mobility-related considerations.

Airlift Deployments

Figures A-1 and A-2 show the airlift-only closure profiles for four specific types of Army divisions, as well as the relative differences in total tons moved. All available airlift was assumed to be allocated in these comparisons. Figure A-1 shows the requirements, excluding support unit weights, being deployed by air. The airborne division can be deployed under these conditions in about a week, while a heavy division takes about 3 weeks. In these examples, the light division took 2 days longer than the airborne division despite the fact that it weighed less because it was moved from a West Coast origin.

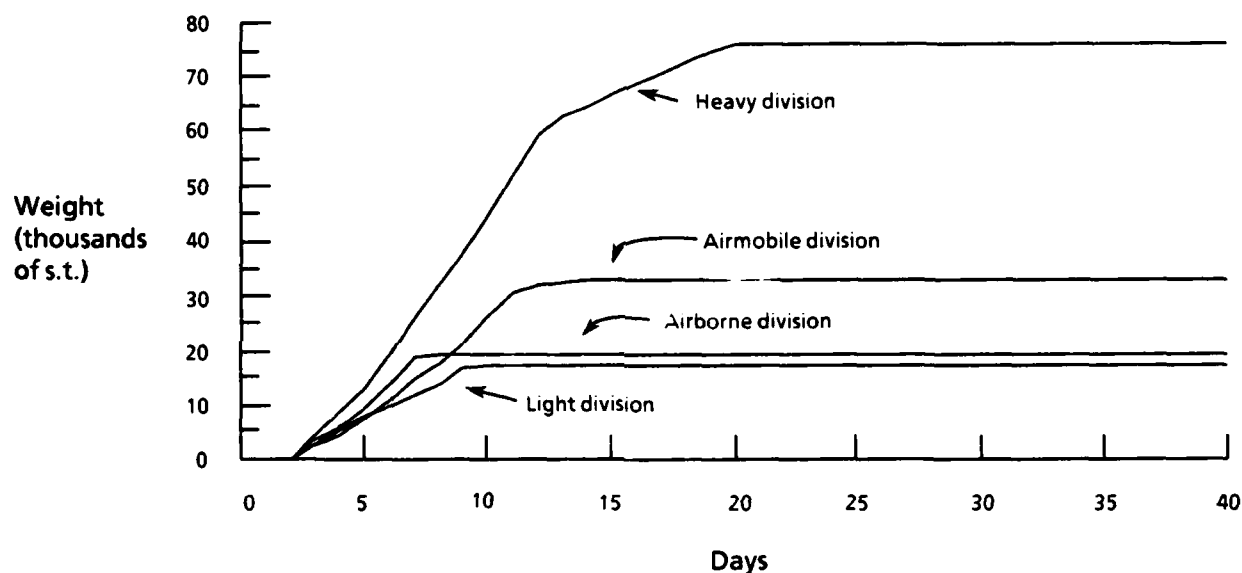


FIG. A-1. TYPE ARMY DIVISION DEPLOYMENTS BY AIRLIFT WITHOUT SUPPORT

Figure A-2 shows the same types of units deploying by air with support unit weights included. The closure difference between the light and heavy units is now almost 4 weeks. One of the fundamental relationships we explore is clearly evident: lighter divisions generally take less time to close than heavier divisions, and the additional requirements for the support units increase the airlift closure differences among the four types of units. Bear in mind that these comparisons involve only airlift, at an assumed availability of 100 percent. As we will see, sealift availability changes the comparisons.

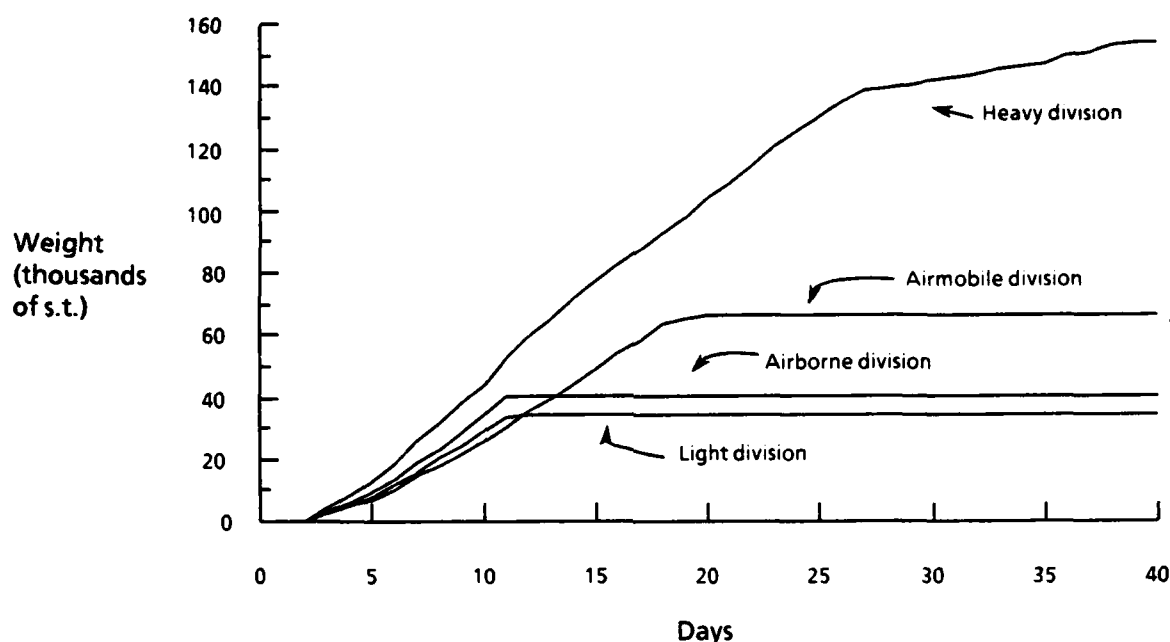


FIG. A-2. TYPE ARMY DIVISION DEPLOYMENTS BY AIRLIFT WITH SUPPORT

Sealift Deployments Compared with Airlift

The next useful deployment comparison is that between airlift and sealift for the same types of units, as shown in Figures A-3 through A-6. In a comparison of the airlift and sealift deliveries of a light division (Figure A-3), it is apparent that sealift cannot compete with airlift. Even with the support units included, airlift still has the potential to close the units prior to the opening of a sea line of communication (SLOC).

In contrast, a heavy division deploying by air barely closes prior to the opening of the SLOC (Figure A-4), and when the support is added to the requirement, airlift can no longer compete with sealift. In viewing these figures, recall that they are based on the assumption that all of the available airlift [total Military Airlift Command (MAC) inventory plus Civil Reserve Air Fleet (CRAF) Stage III] is devoted to these specific movements. In an actual deployment, that much airlift would not be available for these specific requirements. Later in this appendix, we show the sensitivity of the results to the assumed level of allocated airlift. However, since only a relatively few ships are required in these examples and they are probably available,

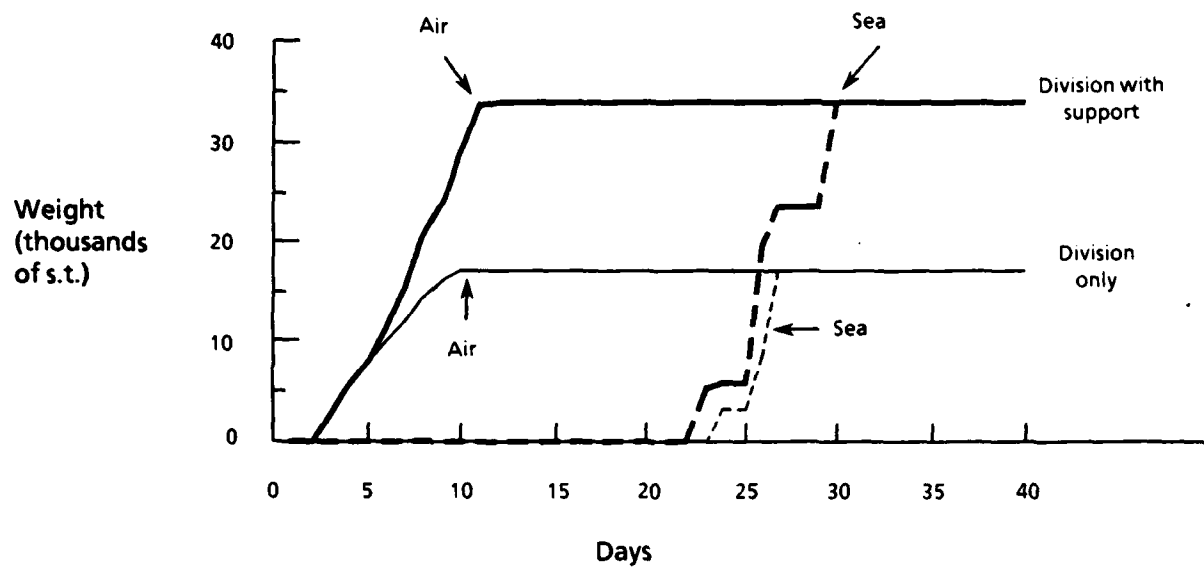


FIG. A-3. LIGHT DIVISION DEPLOYMENTS BY AIRLIFT AND SEALIFT WITH AND WITHOUT SUPPORT

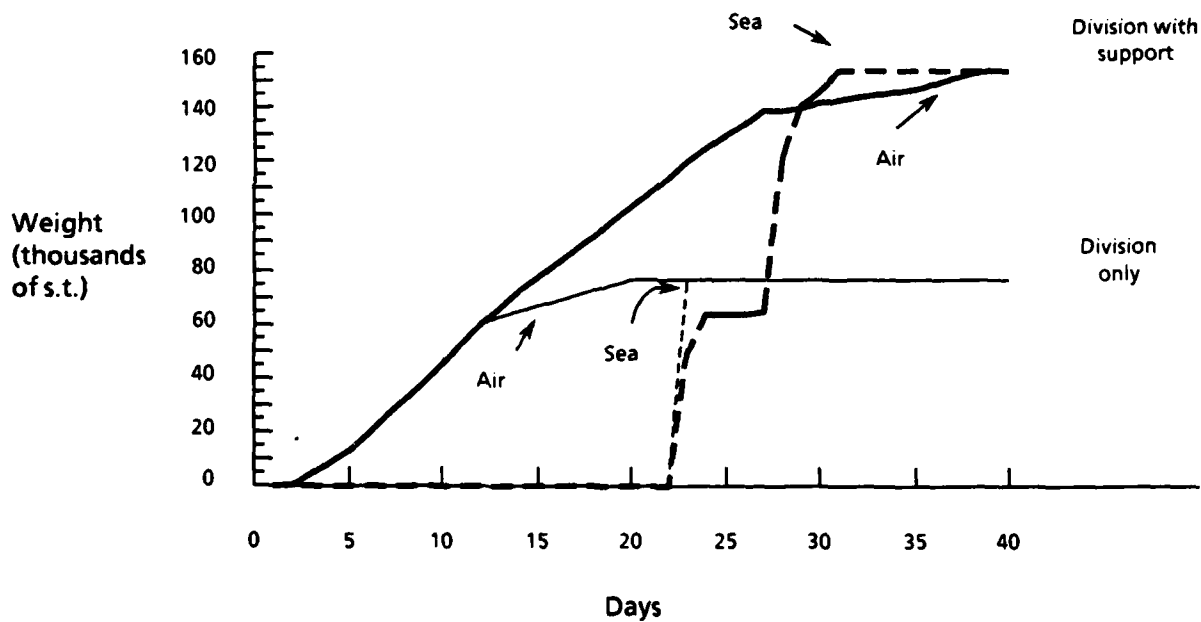


FIG. A-4. HEAVY DIVISION DEPLOYMENTS BY AIRLIFT AND SEALIFT WITH AND WITHOUT SUPPORT

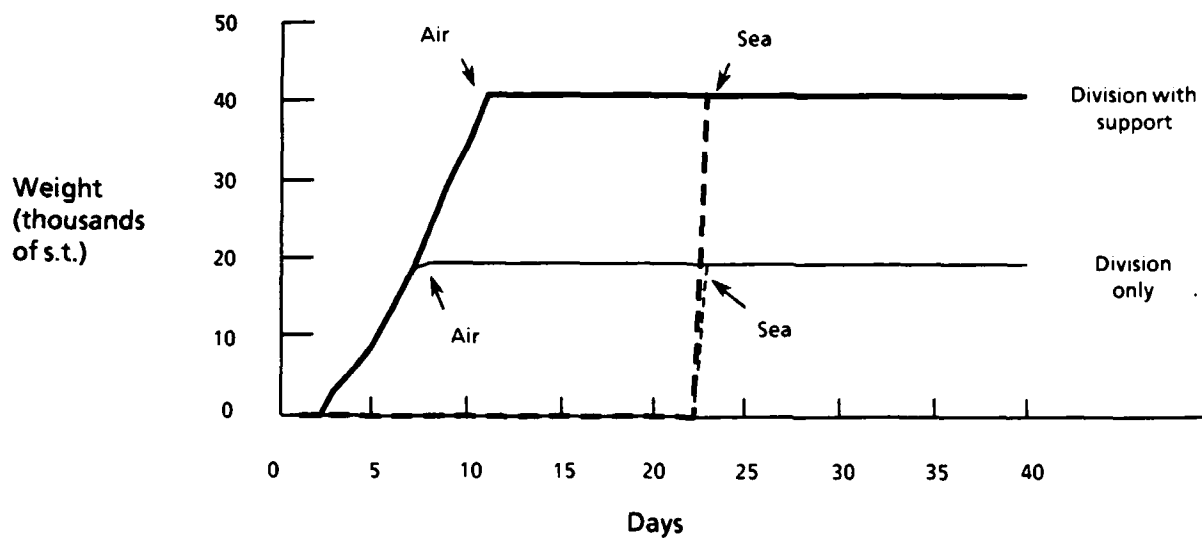


FIG. A-5. AIRBORNE DIVISION DEPLOYMENTS BY AIRLIFT AND SEALIFT WITH AND WITHOUT SUPPORT

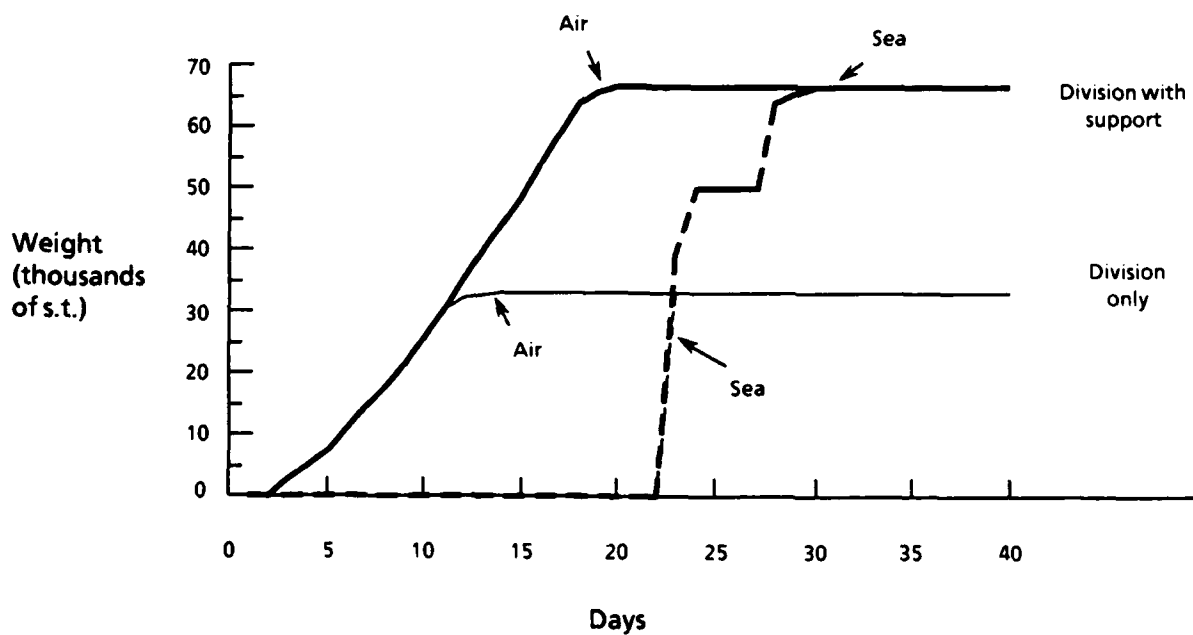


FIG. A-6. AIRMOBILE DIVISION DEPLOYMENTS BY AIRLIFT AND SEALIFT WITH AND WITHOUT SUPPORT

the sealift shown is more likely to be replicated in an actual deployment. For that reason, the advantage shown for airlift in these figures is somewhat overstated.

Figures A-5 and A-6 show the same relationships for the airborne division and airmobile division that we just described for the light and heavy divisions. The observation that the relative advantage for airlift diminishes as requirements increase is reinforced in Figures A-5 and A-6, and it does not matter whether the increase is caused by the additional weight for support units or the additional weight for heavier combat units. One condition worth mentioning is that these simulations use loading and unloading time factors for aircraft and ship types and marry-up times to reflect unit reconstitution at their destinations. The degree to which those factors represent the actual breakdown and preparation of equipment for an air move, in contrast with a sea move, varies widely.

The Effect of Critical Assumptions

In the previous discussion, to highlight differences, we showed the relationship between airlift and sealift deployments for various types of units with and without support packages and under the assumption that the entire airlift and sealift fleets were dedicated to each individual movement requirement. We showed that the time required to complete each move was a function not only of the mode but also of the relative size of the requirement. In this section, we explore the effect of changes in selected critical assumptions: the percentage of airlift assumed available, the use of the CRAF, and the use of U.S. flag shipping.

Airlift Apportionment of 50 Percent

Assuming that 100 percent of the available airlift was allocated to a specific movement problem is useful in establishing analytical benchmarks, but that assumption does not represent what could actually be achieved. Airlift will always have multiple claimants, such as other deploying units or support for continuing other worldwide operations. Planners building a time-phased force deployment list (TPFDL) would use the Joint Strategic Capabilities Plan (Annex J) to determine the initial planning apportionment and would then adjust as necessary on the basis of the urgency of the specific contingency. We are merely comparing air and sea deployments; an assumed airlift apportionment of 50 percent may be no closer to the actual apportionment than 100 percent, but it demonstrates that the judgment a planner makes about mode selection is dictated by the size of the requirement and the

amount of airlift available. In the individual type unit examples we used to explore variations in assumed levels of airlift, we did not consider sealift availabilities to be a limiting factor. Only when the requirements are combined into larger force movements does the question of sealift availability become important. We explored that question separately, and the results are discussed subsequently in this appendix.

Figure A-7 shows the effect on closure for an airborne division and its support if available airlift is reduced by 50 percent. For these units, at the weights shown, such a reduction still allows the unit to close before the SLOC can be opened, but instead of almost a 2-week difference between airlift and sealift, the airlift advantage is reduced to less than a week.

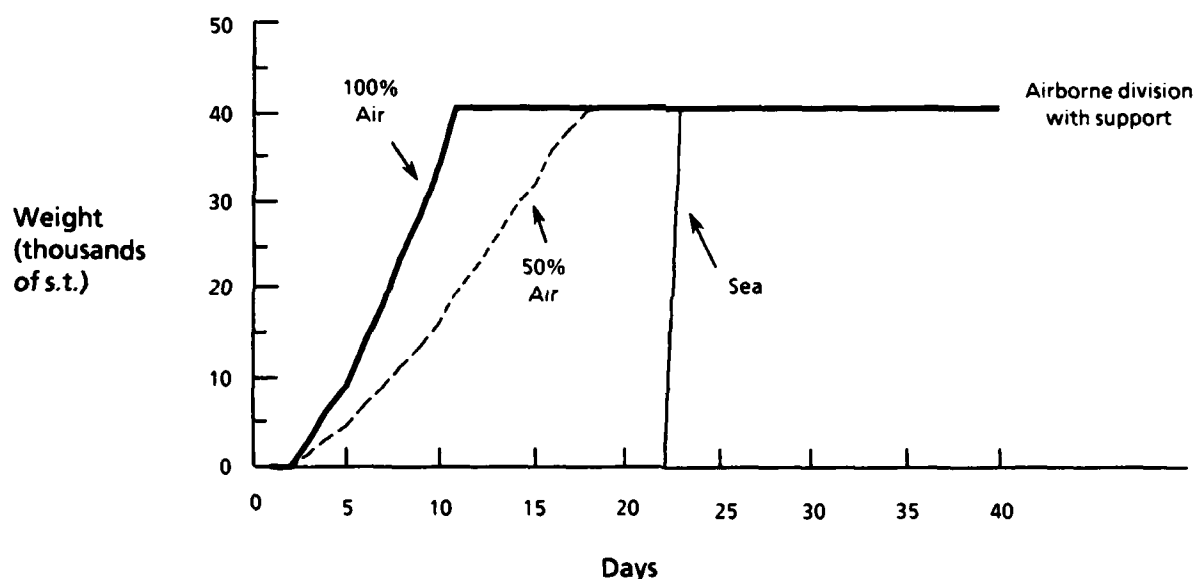


FIG. A-7. AIRBORNE DIVISION DEPLOYMENTS BY AIRLIFT AND SEALIFT
(Comparison of 100 percent and 50 percent airlift)

At a reduced allocation, the airlift advantage over sealift disappears when a heavy division is deployed (Figure A-8). Although not shown, it is apparent that including the support requirements would only be to the sealift's advantage.

The effect of reducing available airlift is similar for the two types of divisions examined earlier; the light division profile (not shown) resembles the airborne division in that at the lower amounts of airlift, the division and its support are delivered prior to the SLOC being opened, but the airlift time advantage is sharply

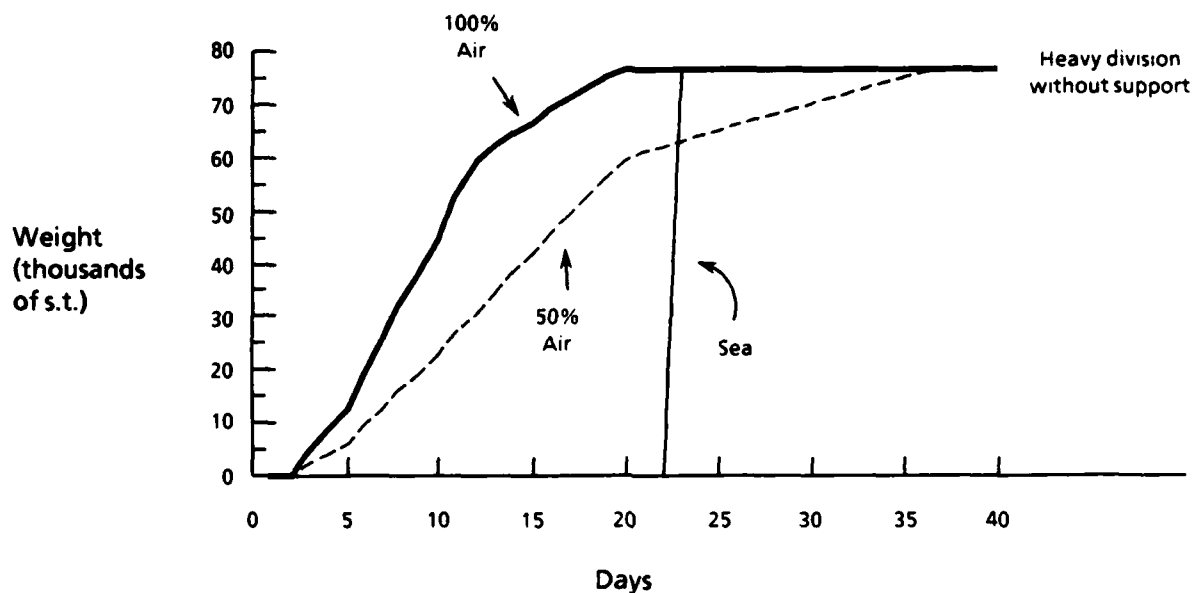
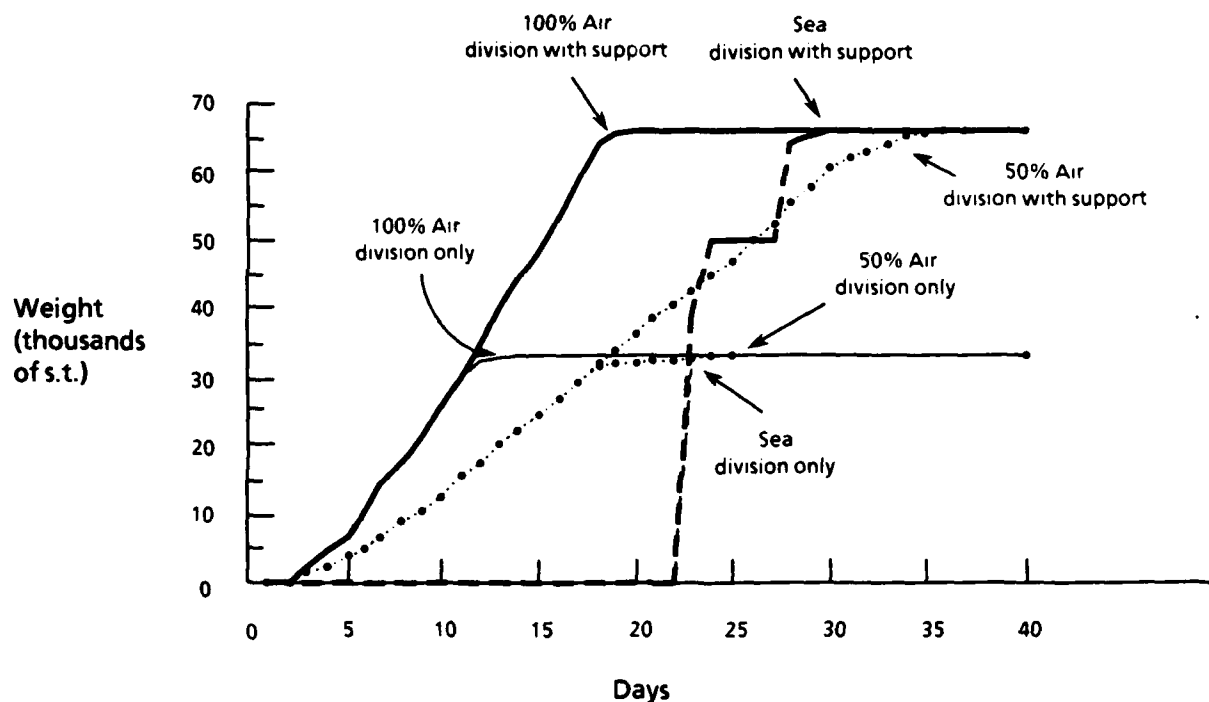


FIG. A-8. HEAVY DIVISION DEPLOYMENTS BY AIRLIFT AND SEALIFT
(Comparison of 100 percent and 50 percent airlift)

reduced. For the airmobile division deploying with reduced airlift, shown in Figure A-9, airlift and sealift take almost the same amount of time, but when the support requirements are included, sealift is able to deliver faster than airlift. Figure A-9 is complicated; it has six different deployment curves and shows in a single graphic example that determining how long it takes to deploy anything depends on many variables.

From these examples, we see that the relationship between airlift and sealift is primarily determined by the amount of cargo that can be delivered by air prior to the arrival of the first ships. The amount deliverable by air is not only a function of the amount of airlift available but also of the type of commodity being moved. Distance, while not a factor in these examples since it was constant, also can have a significant effect on the amount of cargo that can be delivered in a specified period of time by air and sea. The problem is dynamic, and its solution is dependent on many interactive variables, all of which have the potential to affect firepower build-up.

One example of variable data is the day the SLOC opens. Our graphs show the first ships arriving on Day 23; that arrival reflects the use of fast ships; the early availabilities of those ships; and specific origins, destinations, and routing. For



**FIG. A-9. AIRMOBILE DIVISION DEPLOYMENTS
WITH AND WITHOUT SUPPORT**
(Comparison of 100 percent and 50 percent airlift to sealift)

example, we assumed the Suez Canal was closed. Assuming that it is open changes the airlift-versus-sealift relationship. [Note: The effect of that assumption is shown subsequently in Figure A-18.]

Figure A-10 shows the range of possible airlift delivery curves for the different size requirements, corresponding to the types of units we have used, at the assumed apportionment of either 100 percent or 50 percent, in comparison with sealift deliveries to this theater over time. The upper and lower limits of the airlift curves are a result of the payload variations of the different commodities (types of units) being moved, as well as the differences in assumed capability. As the requirements increase, the differences in deliveries over time become greater. The sealift delivery curve begins at Day 23 and ends at Day 30 when the curve intersects the largest type unit delivery requirement. The airlift advantage exists only for individual requirements which are small enough to be delivered prior to the sealift window of Days 23 through 30.

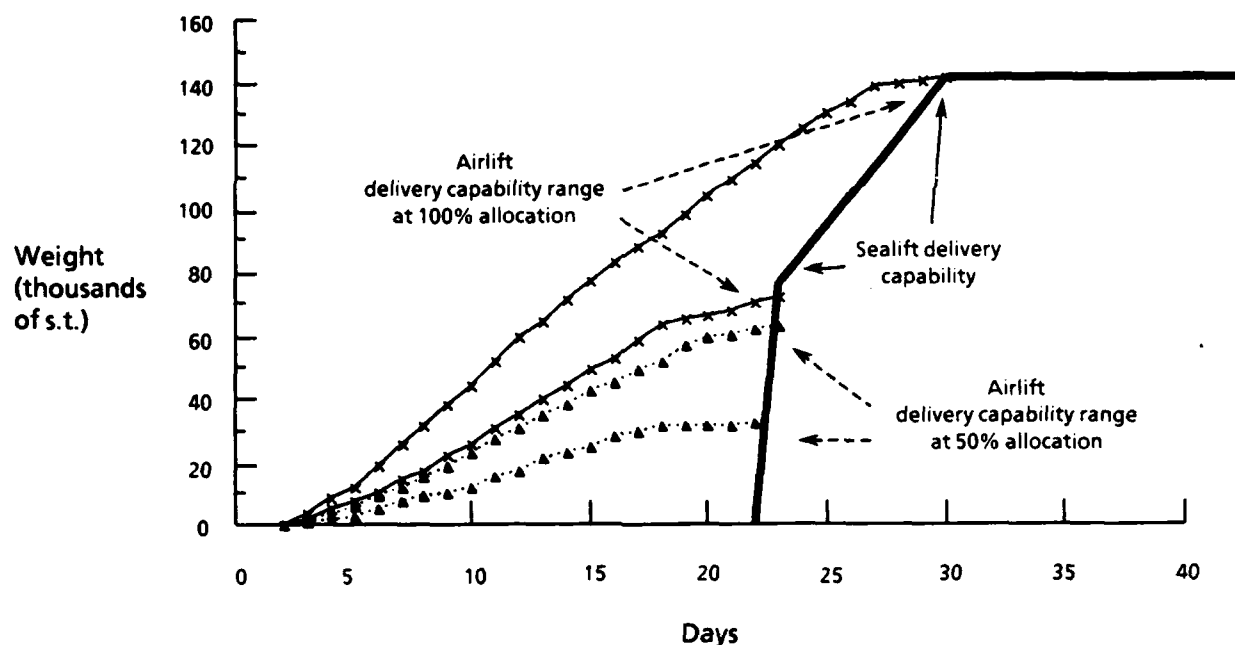


FIG. A-10. AIRLIFT AND SEALIFT CAPABILITY RANGES COMPARED

Civil Reserve Air Fleet Aircraft Not Available

Type Unit Examples. When we address airlift, a significant variable is whether assets of the CRAF are included. Past studies that were oriented toward the reinforcement of NATO almost always assumed the activation of CRAF in stages. Whether the CRAF would be activated to support a smaller contingency is not certain, although the CRAF was activated during the current Persian Gulf crisis. In any event, we should understand the potential contribution of CRAF. The previous examples showing 100 percent and 50 percent of the available airlift apportioned to the deployments assumed full CRAF activation (passenger aircraft only). In this appendix, we show the effect of not activating the CRAF. The most important effect is that MAC C-141B aircraft must be used to carry both cargo and passengers. While an aircraft can be reconfigured from a cargo to a passenger mode and back to cargo if necessary, a far more efficient procedure during a large deployment is to dedicate a portion of the fleet to the passenger-carrying mission. No matter how the MAC fleet is used, if CRAF is not available, the fleet cargo-carrying capability is diminished. The degree to which the deployments are slowed are shown in Figures A-11 and A-12. Again, we see that the effect depends on the size of the requirement.

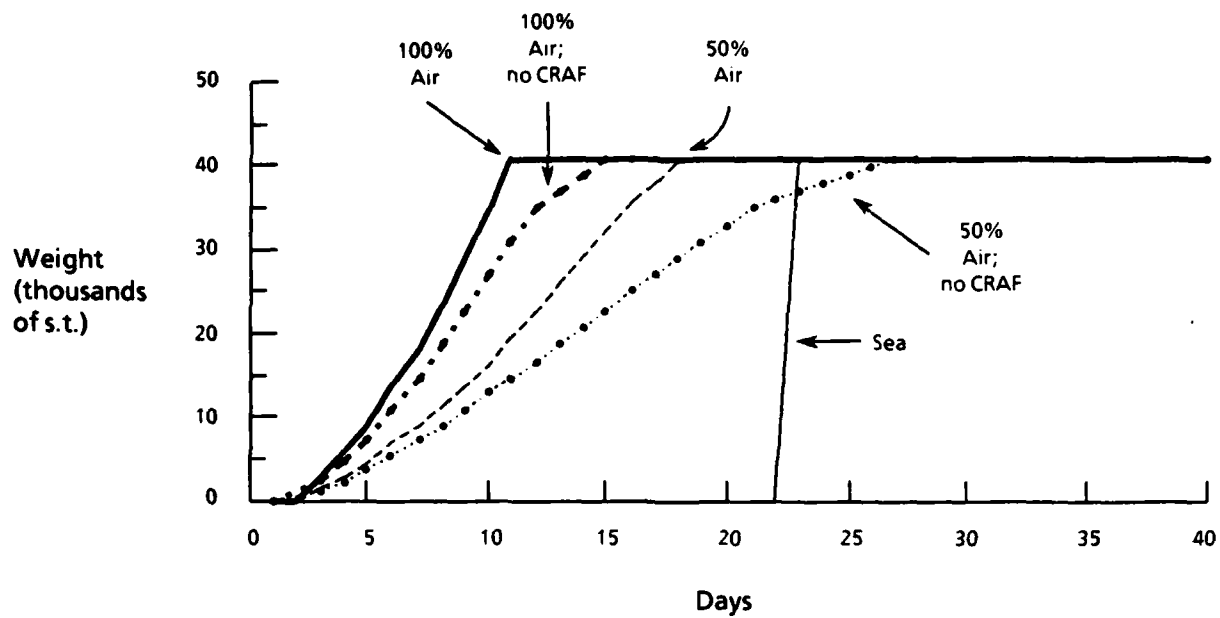


FIG. A-11. DEPLOYMENT OF AIRBORNE DIVISION AND SUPPORT BY AIRLIFT AND SEALIFT
 (100 percent and 50 percent airlift compared with no-CRAF excursions)

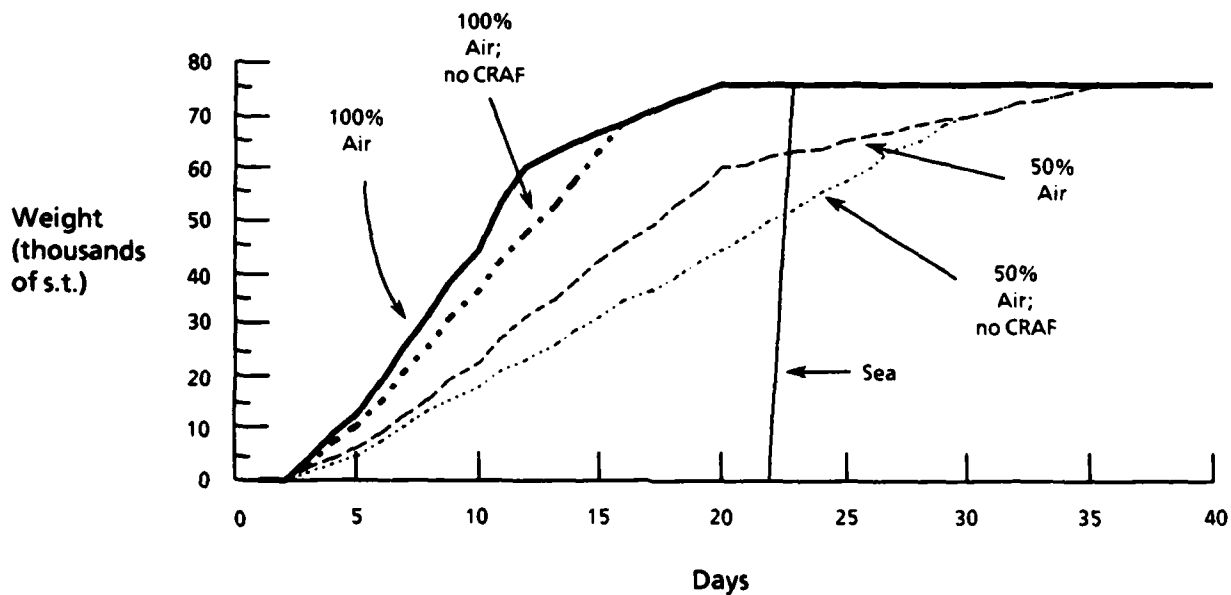


FIG. A-12. DEPLOYMENT OF HEAVY DIVISION WITHOUT SUPPORT BY AIRLIFT AND SEALIFT
 (100 percent and 50 percent airlift compared with no-CRAF excursions)

In Figures A-11 and A-12, an airborne division with support and a heavy division without support are shown, and additional curves are plotted for the case in which no CRAF aircraft are used. The chart shows tons delivered; keep in mind that passenger deliveries are an equally important element of force deployments. In these individual unit deployments, the passenger deployment was usually completed prior to the cargo. For the airborne division, the effect is marginal if the entire MAC fleet is available. If we assume only a 50 percent apportionment of the MAC fleet, that allocation still has more impact than the additional degradation caused by assuming that no CRAF aircraft are available. However, the cumulative effect of both assumptions – 50 percent MAC apportionment and no CRAF aircraft – is that sealift has the potential to deliver the units quicker than airlift. In that instance, sealift could become a viable competitor to airlift, even to deploy an airborne division.

For the heavy division, the constraint is the movement of outsize cargo; the absence of CRAF aircraft does not slow down the closure of the entire division no matter which assumption is made about the percentage of the fleet apportioned to the move. These two figures show that the assumption on apportionment of the MAC fleet is more critical than the contribution of CRAF for *individual unit deployments*. The picture changes, however, when examining the same assumptions in the context of *large force deployments* where CRAF passenger deliveries play a far more significant airlift role.

Notional Force Deployments. In the notional force we used for the force deployment sensitivity excursions, described in Chapter 1, the movement requirement totals almost 2.8 million tons, in contrast with the 77,000 tons for the heavy division shown above. With the larger requirement, the effect of assuming no CRAF aircraft is significantly diminished. Part of the reason is that, just as we saw with individual units, as force requirements increase, sealift plays an ever-increasing role compared with airlift. The airlift/sealift relationship is put into sharper focus, particularly as the relationship to CRAF availability is concerned, as we show the cumulative deliveries of all cargoes by all modes in comparison with air-only and passenger deliveries.

Figure A-13 shows the build-up of tonnage delivered by all modes under three different sets of conditions. First, all available aircraft *including* CRAF are devoted to the deployment; second, all available aircraft *excluding* CRAF are devoted to the deployment; and last, *only 50 percent* of all available aircraft *excluding* CRAF are

devoted to the deployment. The marginal differences can be simply explained; in the context of total force movements, airlift is a minor contributor and when airlift becomes constrained, sealift is able to pick up some of the difference.

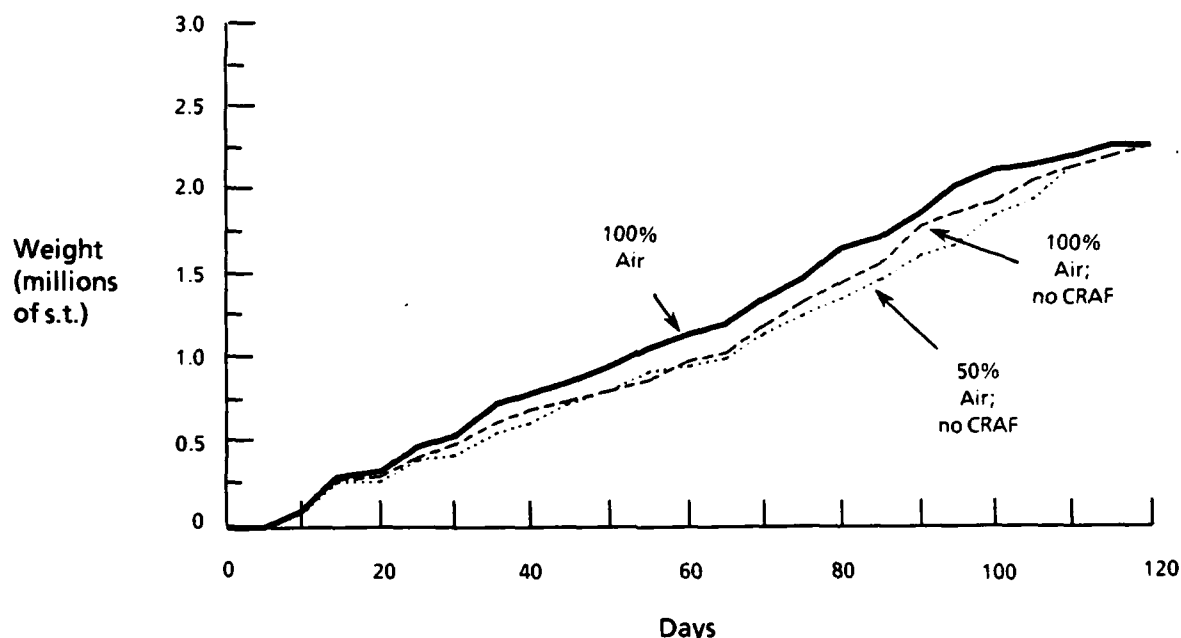


FIG. A-13. EFFECT OF A NO-CRAF ASSUMPTION ON TOTAL TONS DELIVERED BY AIRLIFT AND SEALIFT

Figure A-14 shows the air-delivered tons only. It is apparent that while the cargo delivered by air differs considerably, the effect on total deliveries, shown in the previous figure, is not nearly as significant. However, tonnage is only half the picture. Unit deployments require the movement of people as well, and in that area, the constraints imposed by the absence of CRAF aircraft could be most acutely felt. Since the MAC fleet must move passengers in addition to cargo, the manner in which the fleet is allocated between cargo and passengers will determine the rate at which both commodities move.

In Figure A-15, we see that the loss of CRAF alone does not severely restrict passenger deliveries because the difference has been made up at the expense of cargo deliveries (see Figure A-14). But if the apportionment assumption changes, for example, to the 50 percent shown, the reduced fleet without CRAF has severe passenger delivery constraints. (Since the passengers and cargo are carried on the same aircraft, the higher passenger delivery rate can be maintained in the 50 percent

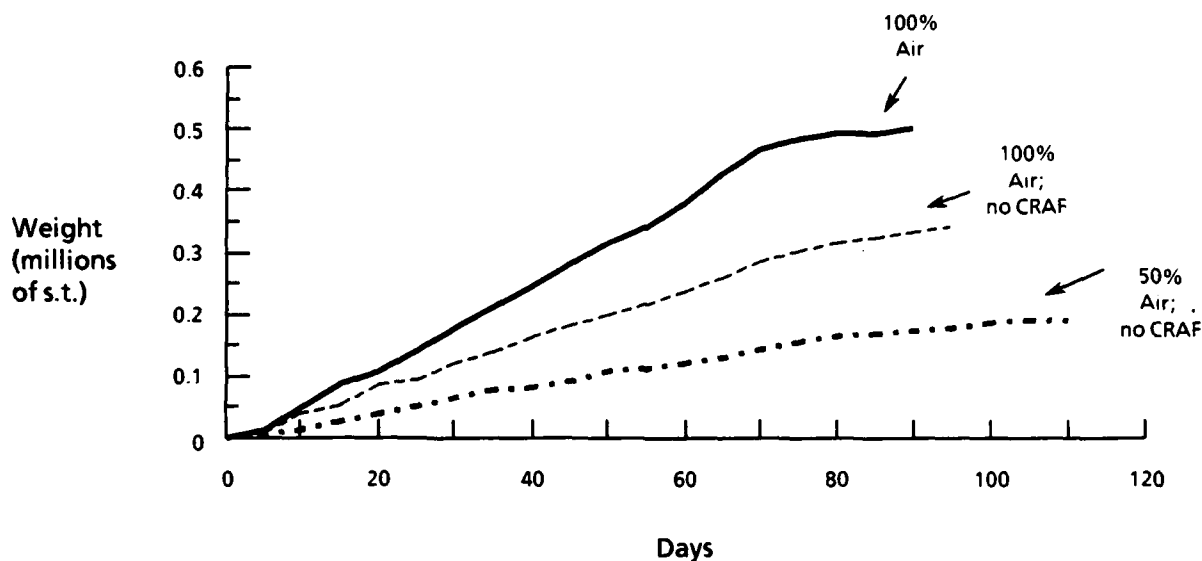


FIG. A-14. EFFECT OF A NO-CRAF ASSUMPTION ON TOTAL TONS DELIVERED BY AIRLIFT IN 100 PERCENT AND 50 PERCENT AIRLIFT ALLOCATION CASES

case but at the cost of an even more drastic slowdown in the cargo deliveries.) In any event, once passenger deliveries are no longer able to keep up with sealifted unit equipment deliveries, the delivery of complete units begins to slow down considerably.

The solution – other than to choose between CRAF activation or no CRAF – is to charter commercial aircraft, either passenger or cargo. That approach is common in peacetime and has been used on a limited basis for emergencies or minor contingency operations. Whether enough commercial aircraft would be available to effect a deployment of this size is doubtful. In any event, commercial charter contributions would result in build-up curves that lie somewhere between the full CRAF and no-CRAF results seen in Figures A-14 and A-15.

U.S. Flag Fleet Not Available

The assumed availability of the U.S. flag fleet is important because that assumption addresses the issues of mobilization and ship requisitioning. The sensitivity of this assumption must be tested in the context of deployment of a force rather than individual units because the smaller requirements can essentially be

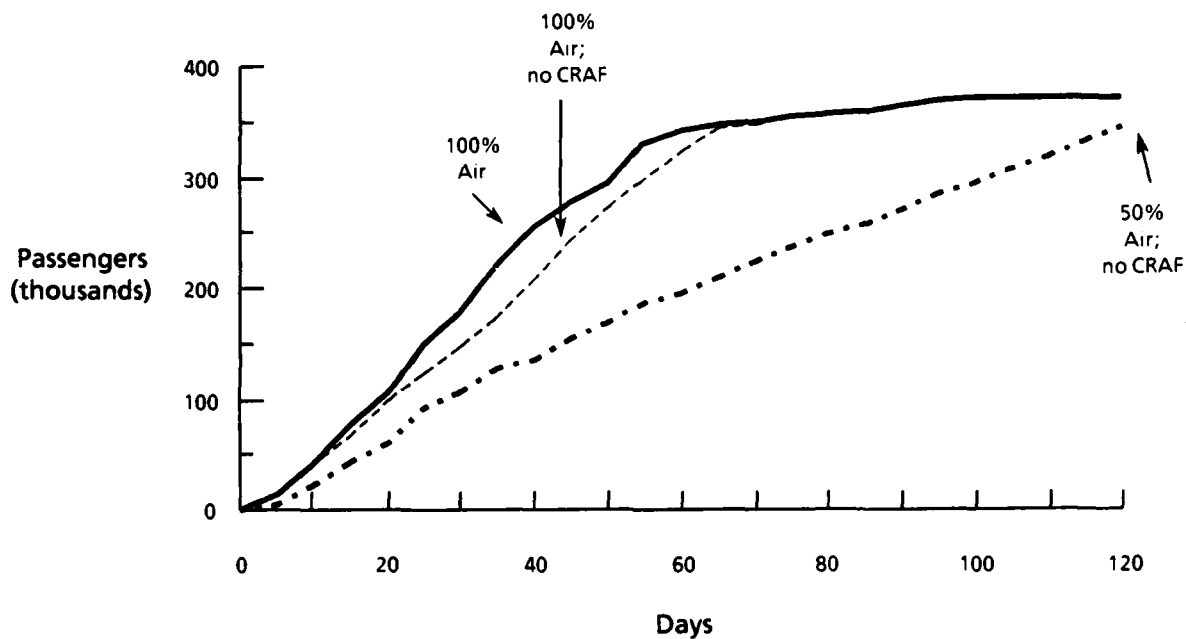
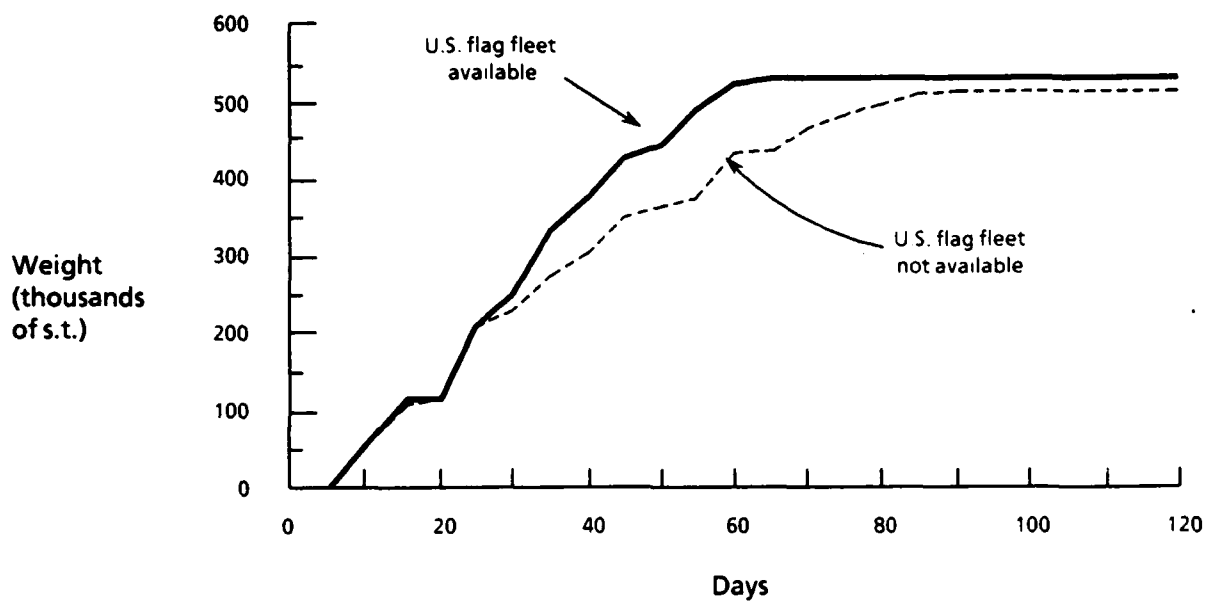


FIG. A-15. EFFECT OF A NO-CRAF ASSUMPTION ON TOTAL PASSENGERS DELIVERED BY AIR IN 100 PERCENT AND 50 PERCENT AIRLIFT ALLOCATION CASES

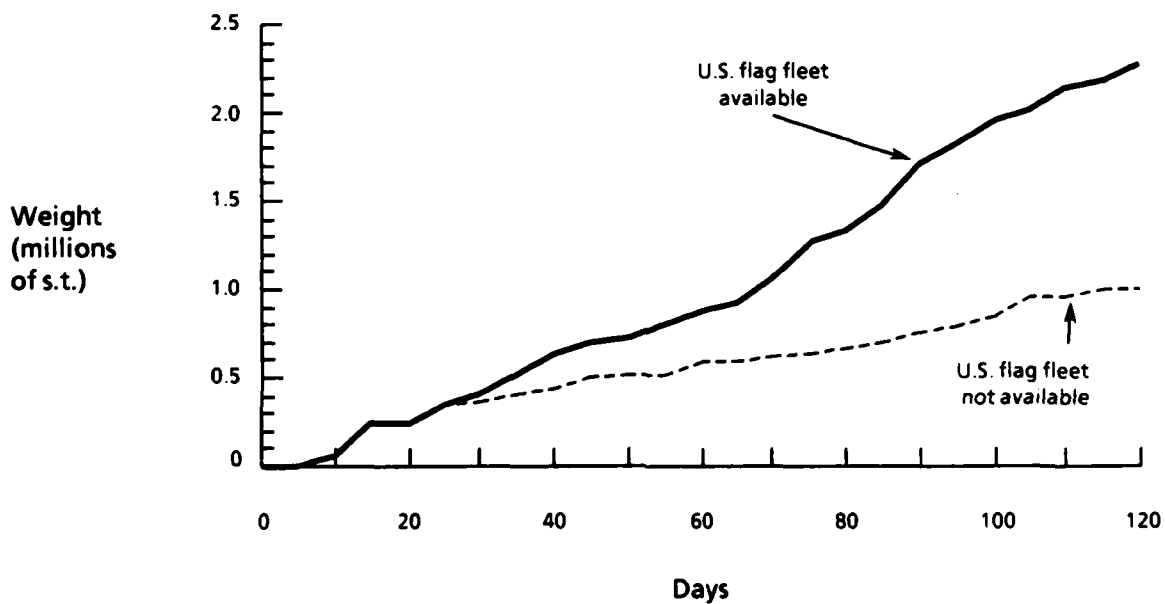
satisfied using Government-owned sealift assets, either within the Military Sealift Command (MSC) fleet or within the Ready Reserve Force (RRF).

Unit equipment deliveries by sea are shown in Figure A-16, comparing a case that includes the U.S. flag fleet with one that did not. While the delivery of unit equipment in the latter case is degraded, it is not serious because some of the shortfall can be deployed by air. The more important point in the case of unit equipment is that the MSC fleet and the RRF ships, if fully activated, are able to handle all the early unit equipment requirements.

In contrast, when looking at all cargoes delivered by sea under the same two sets of conditions (Figure A-17), we see a very different picture. After 120 days, the shortfall is more than a million tons of cargo. Thus, the real contribution of the U.S. flag fleet is in sustaining the force, more than deploying the force (if the RRF is available for the deployment). In fact, depending on the assumptions made about airlift, it would be easy to conclude that a force this size deploying to the Middle East and building up at this rate cannot be sustained without U.S. flag ships if combat is necessary beyond the time when prestocks and basic loads are exhausted.



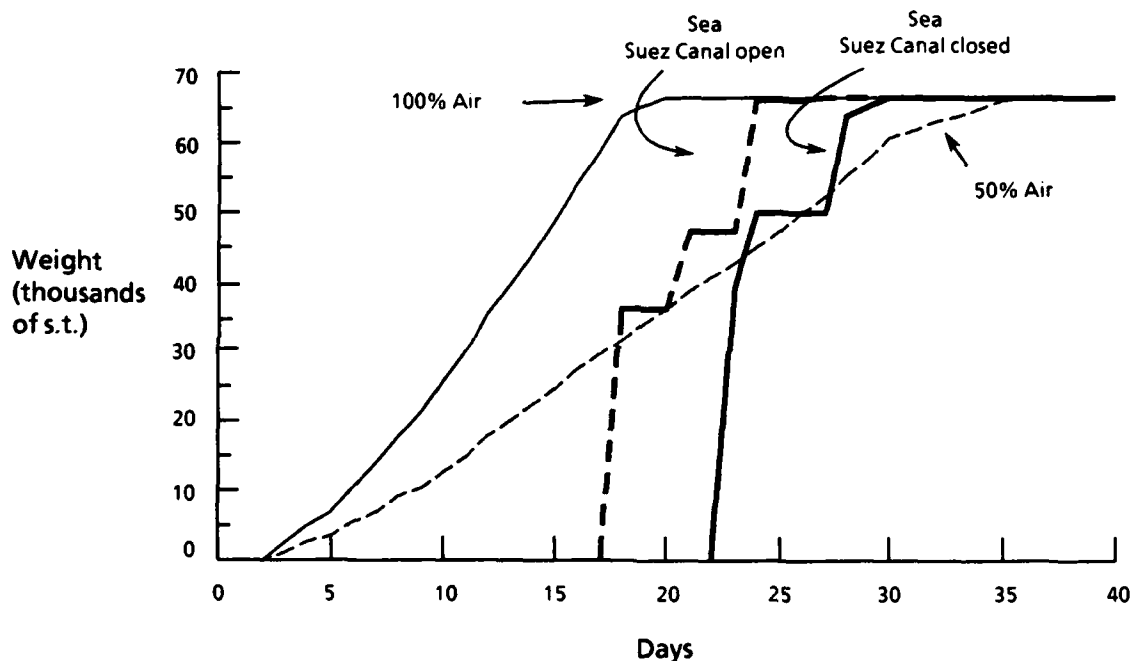
**FIG. A-16. CONTRIBUTIONS OF THE U.S. FLAG FLEET
TO UNIT EQUIPMENT TONNAGE DELIVERED BY SEALIFT**



**FIG. A-17. CONTRIBUTIONS OF THE U.S. FLAG FLEET
TO ALL CARGO DELIVERED BY SEALIFT**

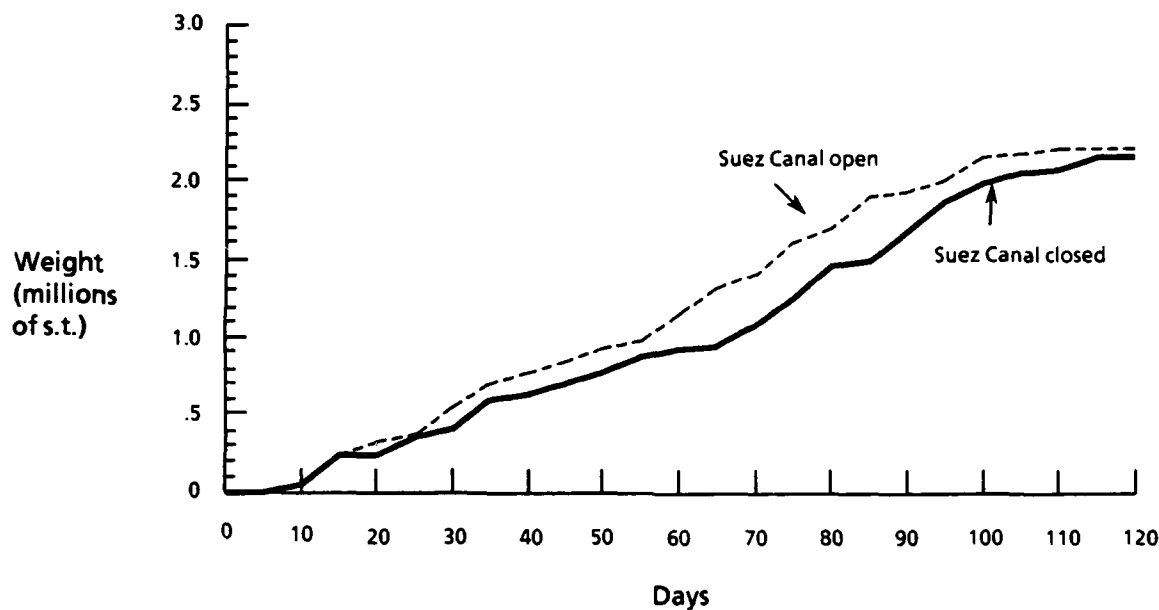
The Suez Canal Is Open

An important assumption affecting sealift deliveries in the Persian Gulf region is whether the Suez Canal is used for shipments from the U.S. East Coast or Gulf Coast. If the canal is open, the distance is approximately 3,400 n.mi. less from the East Coast and 2,600 n.mi. from the Gulf Coast. The shorter distances equate to decreases in the transit time of 5 to 9 days from the East Coast and 4 to 7 days from the U.S. Gulf Coast, depending on the ship type and speed. For large force deployments, the difference in tonnages delivered over time is less dramatic (see Figures A-18 and A-19).



**FIG. A-18. AIRMOBILE DIVISION WITH SUPPORT
COMPARING 100 PERCENT AND 50 PERCENT AIRLIFT TO SEALIFT
(Suez Canal open versus Suez Canal closed)**

Figure A-18 uses deployment of an air assault division and its support as an example to show that with the canal open, sealift becomes highly competitive with airlift if fast sealift ships are used from U.S. East Coast ports for part of the movement, cutting the deployment times by 3 to 5 days. Figure A-19 shows the effect on the deployment of the entire force. The result is less dramatic because, unlike specific unit moves that originate on the East Coast, the curves in Figure A-19 reflect



**FIG. A-19. TOTAL CARGO DELIVERED BY SEA
(Suez Canal open versus Suez Canal closed)**

movements from all U.S. coasts, some of which are not affected by the status of the Suez Canal. Nevertheless, at Day 30, in the case in which the canal is open, almost 150,000 additional tons have been delivered; at Day 60, that number increases to more than 220,000 tons.

Assumption Summary

In this section, we have not covered all the assumptions that must be made, nor have we displayed the effects of all possible combinations of assumptions. We looked at the question of airlift apportionment, availability of CRAF, availability of the U.S. flag fleet, and the availability of the Suez Canal to illustrate the range in possible solutions. We examined each of these factors independently, recognizing that reality is far more complex, with ever-changing combinations of these three factors interacting. In our base case, which is described in Appendix B, we make judgments about the most likely set of conditions we should assume and combine them. The sensitivity excursions we describe are unrelated to the base case or to subsequent simulations that compare different force build-up sequences and mode selections.

Additional Mobility Considerations

In the preceding discussion of assumptions, we used data showing the deployment profiles of a large force consisting of many units. Some of the differences between deploying a force and deploying individual units are obvious. However, we highlight the complications introduced by a force deployment because in our analysis we seek a "preferable" force deployment sequence and these considerations are affected by the assumptions. (A preferable deployment uses available lift to deliver the maximum, sustainable firepower early.) The following subsections describe additional considerations that affect force deployments.

Requirements Versus Capabilities

The combined airlift and sealift available for a one-time, single lift is sufficient to support many individual unit moves, depending on their size. As units combine with other units and the movement requirement grows, the requirement will eventually exceed single-lift capabilities and queues will develop as units wait for the second and succeeding sorties of aircraft or the second and succeeding sailings of ships. The point at which requirements exceed capabilities is a function of both the requirements and the capabilities. In our discussions of assumed lift available, we address capabilities; converting from individual unit deployments to a force deployment affects the requirement. Our five-division force with support exceeds the tonnage that can be moved by air and sea in a single lift, and the resulting shortfall requires management. Lift shortfall is managed by the establishment of priorities, the use of required delivery dates (RDDs) for each unit, and the assignment of high-priority lift to specific units. The management of shortfall also means the assumption of risk because in a large deployment, many units are needed before they can be delivered.

In the real world, the risks associated with any decision to deploy units in a particular sequence are highly dependent on the scenario at the time the deployment is taking place. For that reason, even though we have attempted to illustrate different solutions, we recognize that many other factors must be considered in determining a final sequence for a contingency deployment, particularly if the requirement significantly exceeds the capability.

Priority

In the individual unit examples, priorities did not have to be established since all available lift assets were applied to the individual requirements. When we added support units, we gave the combat force priority. However, where a force list is developed, the problem becomes more complex. While it may not be difficult to specify that one Army division should receive priority over another, it is not as easy to determine, for example, where the equipment for an Army combat service support unit should fit on a priority list relative to the support equipment required by the Air Force. The assignment of priorities becomes extremely complex if the force list is extensive and includes movement requirements for all Services. The force we used to compare different deployment sequences was large enough that shortfall occurred and had to be managed. Generally, when one gives priority to a unit, one does so at the expense of other units. Specifically, when we gave priority to combat units, we recognized that priority would be given only at some cost to the support units.

Operation Plan Development. Normally, in the development of an operation plan TPFDL, the Services specify their priorities by developing their own RDDs. If the aggregated requirements exceed available lift in any time period, detailed discussions between the supported Commanders in Chief (CINCs) and the Services [time-phased force deployment data (TPFDD) refinement conferences] ultimately result in an integrated TPFDL which meets the CINCs' desires and can be deployed with the available lift.

Our Study. In this study, without the benefit of a detailed refinement conference process, we gave lift priority to Air Force tactical fighter squadrons only. All other unit RDDs were treated as variables, with many possible deployment sequences constructed. We frequently changed RDDs for individual units to establish different priority sequences. The arrival profiles we developed for specific units are thus a product not just of the lift available but also of the priority given to the specific unit in relation to all other units within the force. Through this mechanism, we balanced the three elements that comprise the subject of the study: mobility, sustainability, and firepower. Although our solutions ultimately satisfied the conditions that we established, other solutions may satisfy the same conditions. We made no attempt to develop a detailed TPFDL; rather, we conceptually explored relationships.

Mode Selection

When examining individual unit deployments, the comparison between air and sea deliveries is straightforward because the deployments begin as soon as units arrive at the ports of embarkation and loading is completed. In a large force with units competing for lift, the comparisons are not as clear because if a mode is specified, units may have to wait for the specified lift to become available. In most of our simulations, many of the movements require a mode designation; i.e., Marines on amphibians, Air Force by air, etc. For other types of units, a mode designation may be desirable, but not required.

Our purpose was to find a more effective use of the available airlift and sealift, independent of operational considerations. Thus, in some cases, we explored deploying an airborne division by sea to free up the airlift typically devoted to it, and we experimented with deploying heavy divisions or brigades by air instead of the more typical sealift mode. Each of these decisions affected the delivery of all other units in the force.

Pre-positioning

Pre-positioning, or the storage of equipment in a possible future area of operations, is a mobility option that has great potential for reducing deployment times. However, we did not demonstrate the effects of pre-positioning in this study because we limited our options to the use of existing mobility assets. Nevertheless, pre-positioning may be the only realistic way to significantly reduce deployment times to the Middle East. As lessons are learned from the Operation Desert Shield deployment and future mobility programs are either modified or created, the option of pre-positioning deserves consideration, and for that reason, we present the following observations.

Several programs can serve as pre-positioning models; and each has advantages and disadvantages. The Marine Corps Maritime Prepositioning Ships (MPS) is an afloat pre-positioning program with equipment configured in unit sets. While it is more expensive than land-based storage, it is more flexible and does not depend on negotiations with host countries. The fact that this program already exists (assuming it will be reconstituted when the current crisis is over) means that the greatest potential for expediting a Southwest Asia deployment is to be gained by significantly expanding Army pre-positioning. The Army already has experience in

Europe with the prepositioning of materiel configured to unit sets (POMCUS) program. A similar program for Southwest Asia, with combat and support equipment arranged in unit sets rather than as individual war reserves, should be given serious consideration. The afloat pre-positioning ships already based in Diego Garcia and utilized in Operation Desert Shield have limited amounts of unit equipment, mostly support units. The bulk of the Diego Garcia pre-positioning consists of consumables.

The advantage of pre-positioning unit equipment can only be realized if sufficient airlift is made available early in a deployment to move the personnel and equipment that has not been pre-positioned. As the size of the pre-positioning program grows, so too do the demands for early airlift. A point is reached beyond which pre-positioning no longer makes sense, and that is the point at which units wait longer for airlift than they would have if their equipment were deploying entirely by sea. Creation of unit equipment pre-positioning programs for the Middle East must have a corresponding commitment to early sequencing in the TPFDL for the movement of passengers and more important, to intensive management of the equipment to ensure that residual movement requirements are minimal.

SUSTAINABILITY

Introduction

Force sustainability is a complex subject with many aspects. Our principal focus is to show the role that mobility and sustainability play in developing deployed combat power. In the previous section, we showed that combat power build-up is sensitive to many variations in mobility capability; here, we demonstrate that sustainability plays an equally important role in determining the rate at which effective combat power can be deployed. We divided sustainability into two parts: the nondivisional combat service support units required to deploy with a combat force and the consumable supplies required to give the combat force the capability to fight and survive. Without adequate levels of either, the combat force has little utility other than to serve as a political show of force.

Support-to-Combat Weight Ratios

A critical variable in combat force deployments is the amount of lift dedicated to support units, particularly early in the deployment sequence. No magic formula

exists. Planners developing TPFDD in support of specific plans or contingencies attempt to integrate particular support units into the deployment sequence as they are needed. However, since most ground combat units deploy as brigades and divisions while support units deploy as detachments, companies, or, (infrequently) battalions, the support force almost always has to "play catch-up" for the first 60 days.

In this study, we considered the allocation of lift to support units an important factor. To measure the force sustainability, we created a measure of comparison based on the weight of support units deployed relative to the weight of the combat units deployed. We had difficulty determining what an acceptable ratio looked like, both in terms of the total weight deployed and the ratio as the deployment was occurring. We examined various movement requirement databases developed by the Services and then constructed a database with support-to-combat ratios consistent with the Services' original data. For example, the Army Southwest Asia scenario database had a requirement for approximately 2 tons of support unit equipment for every ton of combat unit equipment. Since that requirement fit the range of values we had examined in other studies, we accepted the 2:1 ratio as one of our measures of force sustainability. That ratio represented the force after the theater build-up was completed. We were then left to determine the sequence in which the combat force build-up should occur, and measure the impact on the support force by using the support-to-combat weight ratio.

Our objective was to determine subjectively whether the deployment sequence ensured force sustainability as far as combat service support units were concerned. A wide range of factors can be considered in making such a determination; a detailed assessment of force sustainability would require a function-by-function assessment as the force deployed. Reducing that complicated process to a simple ratio based on unit equipment tonnage delivered obviously leaves many questions unanswered, but we feel the use of the ratios is a reasonable measure of the potential for sustaining the force. If we determine the objective ratio to be 2:1 by looking at a fully developed force deployment list, it is reasonable to assume the force could not be sustained if the ratio were, for example, less than 0.5:1 after 30 days. We believe that deployment to a bare base environment in which no forward deployed forces are in place requires establishment of a 1:1 ratio as a minimum early in the deployment if the force is to have any chance to engage in even limited combat operations. If the probability of

combat is unlikely, at least early in a deployment, the risk associated with an unbalanced deployment is reduced. Even in the case in which combat is imminent, the objective 2:1 ratio does not have to be maintained throughout the deployment because some logistical functions can be deferred until the deployment is completed.

Our base case (defined in Appendix B) support-to-combat ratio is shown in Figure A-20. The early phase of a deployment is usually all airlift, augmented by the breakout of pre-positioned supplies if available. In Figure A-20, the low support-to-combat ratio indicates that combat units received the majority of the early airlift available. The dip on Day 23 reflects the arrival of the fast sealift ships with predominantly combat units aboard. Those arrivals precede the establishment of the SLOC (when most ships begin to arrive) by about a week. At that time, the ratio begins to increase. This base case depiction is consistent with the way we have traditionally built our deployment requirement databases and TPFDLs. From the perspective of force sustainability, we believe that the risks are too great with this type deployment sequence primarily because of the extended time between the arrival of the first units and the arrival of sufficient support units to provide even marginal support. Not until Day 34 does sufficient support capability begin to develop.

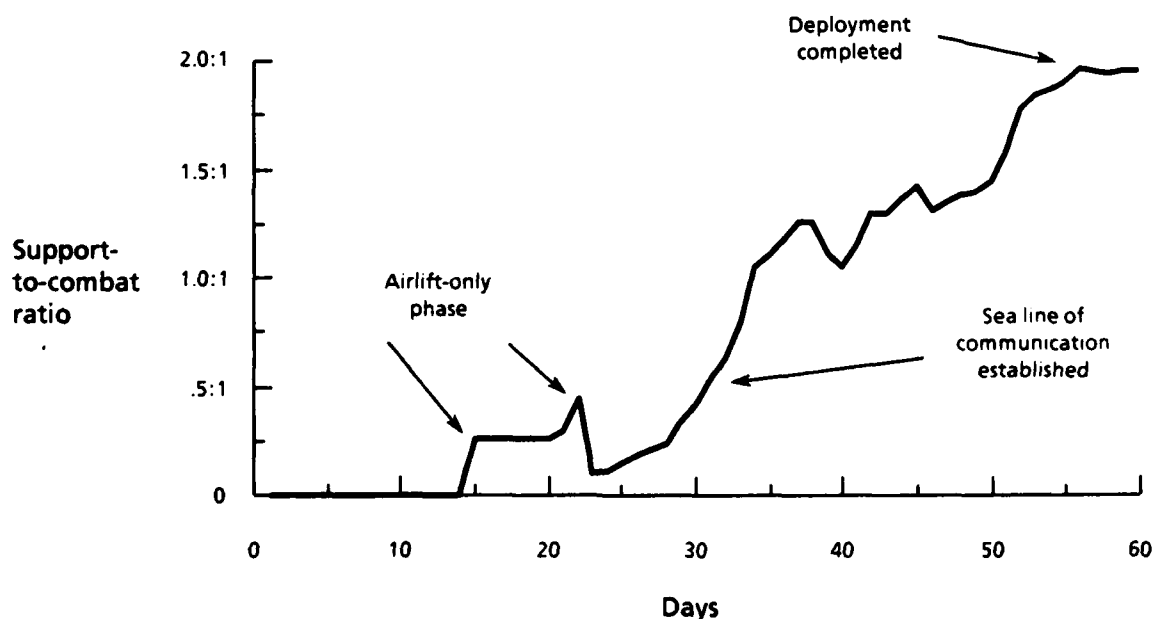


FIG. A-20. BASE CASE SUPPORT-TO-COMBAT RATIO

Given our intention of trying to find a "proper" mix between firepower and sustainability, we concluded that the base case was an unacceptable solution because the force was not sustainable for more than a month. Our subsequent excursions, which are described in more detail in Appendix B, had two purposes: first, to experiment with the combat force deployment sequence to improve the firepower build-up and second, to allocate more lift early to the support forces to improve the support-to-combat ratio.

Consumable Supplies

Another measure of sustainability is days of supply. Calculation of that number, however, is complicated, requiring data on the beginning stockage position if any (pre-positioned stocks), the rate of consumption, the stockage build-up objective, the availability of stocks to be shipped, etc. Each of those factors requires detailed calculations and differs greatly by class of supply and by Service. For our illustrations, however, it is possible to simplify the problem of measuring the potential impact that consumable supplies may have on force deployment. Using the Army component of our notional force only, the programmed levels of pre-positioned stocks in that objective theater, and a theater-level consumption factor, we calculated the days of supply for dry cargo (less ammunition) available in our base case. (The ammunition calculation is more complicated, requiring assumptions on when the first day of combat occurs in relation to the force build-up; further, using theater-average consumption factors is not useful because ammunition consumption factors actually vary significantly for different types of units). Figure A-21 shows the differences in the days of supply resulting from two different simulated deployments.

Since the consumption factor and prestock levels were held constant, the only variable that can cause the early differences in the base case and the excursion is the rate of force closure. The excursion has a slower force deployment (not evident in Figure A-21), resulting in later drawdown of prestocked supplies. Once replenishment stocks begin to arrive around Day 43, both cases build back to a 60-day objective at approximately the same rate. Figure A-21 is shown only to illustrate that quantifiable relationships exist between prestock levels, consumption, and the deployment sequence, all of which can be reduced to a measure of sustainability called days of supply. The important point is that an imbalance in the

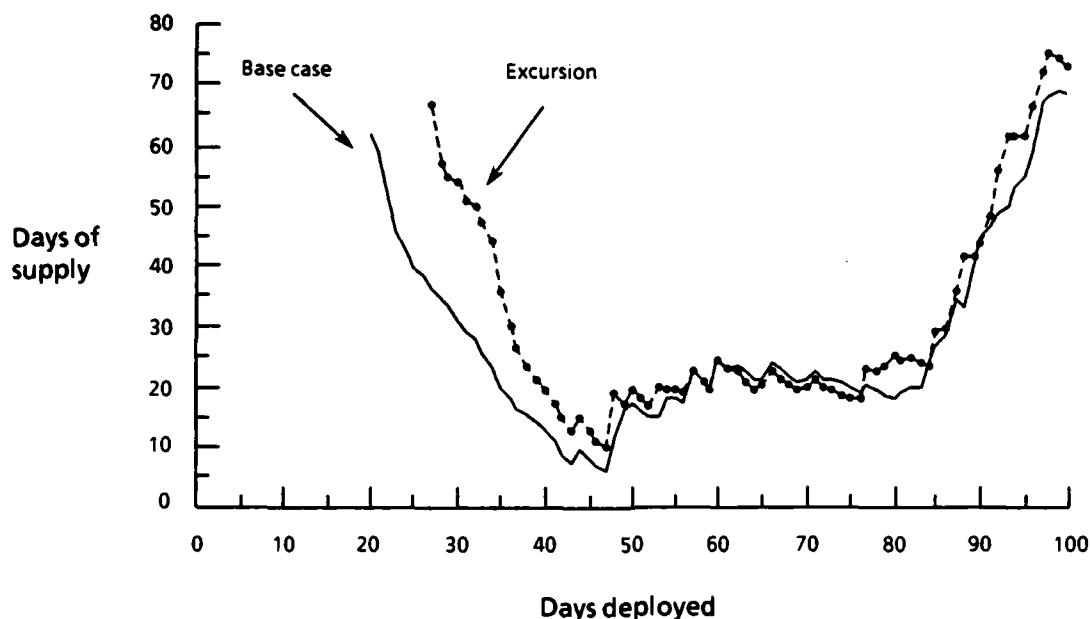


FIG. A-21. DAYS OF DRY CARGO SUPPLY FOR ARMY UNITS DEPLOYED
(Base case compared with an excursion)

days of supply will affect force deployments since lift is allocated to supplies rather than units.

The relationship we are trying to establish is that between the movement of supplies and forces. From Figure A-21, we see that programmed levels of prestocked supplies preclude the need to ship consumables during the same time period that force deployments are occurring. If those prestock levels are not actually achieved, and a rapid build-up of combat forces is maintained, either consumption would have to be curtailed or replenishment started earlier to avoid shortfalls. The problem then becomes iterative; because the movement of supplies begins earlier, the potential exists for conflict with the combat force deployment. If the combat force deployment is slowed down, the rate of consumption slows down and the prestocks last longer. Any number of solutions are possible; we only point out the dynamic nature of the relationship.

Given that our simulations assumed that no combat had begun and thus no ammunition was consumed and that we did not have the detailed data necessary to calculate dynamically changing consumption as deployments changed, we made no

calculations on the days-of-supply variations that would result from different deployment sequences. However, we do know that prestocked supplies are the only way to prevent supply degradations in early force deployment; if supplies must compete with units for airlift, the result is far more significant than it is once the SLOC has opened because, for the most part, different kinds of ships carry units than carry supplies, and adequate ships are available to carry supplies.

Because of the difficulty in making valid calculations on the status of consumable supplies, we limited our measure of force sustainability to support-to-combat weight ratios.

FIREPOWER

Measures of Effectiveness

Force effectiveness has many quantitative measures such as weapons effectiveness indicators — weighted unit values, correlation of forces scores, and techniques for assessing comparative force modernization (TASCFORM) scores. While those scoring systems generally consistently give relative values to various types of units, the different methodologies used to develop the scores produce some differences. We did not examine the different methodologies, but rather, illustrated the effect that the use of available mobility can have on potential firepower build-up. After comparing the various firepower scores for different combat units, we chose to use TASCFORM scores for that purpose. Those scores were developed by The Analytic Sciences Corporation for the Director of Net Assessment, OSD, as a method for indexing general-purpose force modernization based upon the measured performance characteristics of the weapon systems in use. We used them as indices of the relative firepower between different types of units. The actual scores used in developing our deployed firepower build-up curves are classified, but the relative rankings are shown in Table A-1.

Firepower As It Relates to Mobility

In this study, we concentrated on determining the relationship between firepower and the amount of lift necessary to deliver the personnel and cargo that generate that power. We calculated ratios that reflected the relationship between the firepower value and the lift required to deliver both the cargo and the passengers. Although the cargo weight between heavy and light forces differs significantly,

TABLE A-1

RELATIVE FIREPOWER FOR TYPES OF GROUND COMBAT UNITS

TASCFORM firepower ranking	Type units
1	Mechanized division
2	Marine division
3	Air assault division
4	Motorized infantry division
5	Airborne division
6	Light infantry division

passenger movement requirements are similar. Table A-2 shows the comparison between firepower rankings and our calculated mobility/firepower ratio, which reflects the lift required to deliver the associated power. The mechanized division, which has the most firepower, and also the most weight to move, is still ranked first from the mobility perspective because in relative terms the unit provides more bang for each ton-mile or passenger-mile required to deliver it.

TABLE A-2

FIREPOWER RELATED TO MOBILITY REQUIREMENTS

Type units	Firepower rank	Mobility/firepower ratio
Mechanized division	1	1
Marine division	2	See text
Motorized infantry division	3	2
Air assault division	4	4
Airborne division	5	3
Light infantry division	6	5

Note: 1 indicates most firepower and best ratio.

No mobility ranking was established for the Marine division because it is difficult to compare with Army divisions. Marine divisions, particularly those that

include MPS brigades, deploy with support elements and stocks that are an integrated part of the divisions and depend heavily on dedicated sealift rather than common user sealift.

The most apparent difference between firepower rank and the mobility/firepower ratio is the change in position between the airborne division and the air assault division. While the airborne division does not rank high in firepower, it is light, has limited outsize cargo, and is easily deployable by air; thus, for the lift required, it provides a relatively high firepower value. The air assault division, on the other hand, has substantial firepower but requires an inordinate amount of lift because of the number of helicopters that have a very high space-to-weight ratio and large number of personnel.

These static comparisons of the relative mobility required for different types of units were an important intermediate step before beginning the actual deployment simulations. We found that the static (calculated) differences in firepower among the ground combat units were substantial. The question was whether those differences remained visible when the units were deployed along with their support units and all the other claimants for lift. The deployment simulations measured the differences in deployed firepower capability and provided a methodology for rapidly changing the deployment sequence or mode for specific units and recalculating a new firepower build-up profile.

APPENDIX B

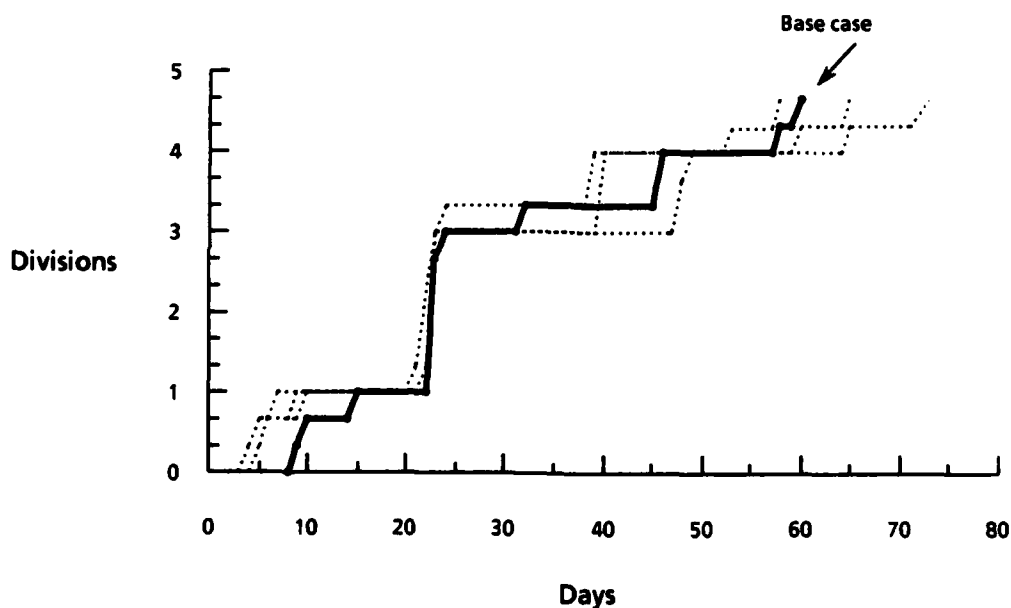
FORCE BUILD-UP COMPARISONS

FIGURES

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FORCE BUILD-UP COMPARISONS

In Appendix A, we describe the variations and analytical uncertainties that complicate calculations involving mobility, sustainability, and firepower. In this appendix, we describe the details that bring together the mobility and sustainability issues as they potentially affect firepower build-up. We have considered many possible data and assumption variations to reach this point. Some of the force build-up curves resulting from those different assumptions and conditions are shown in Figure B-1.



**FIG. B-1. BASE CASE FORCE BUILD-UP
COMPARED WITH DEVELOPMENTAL SENSITIVITY CASES**

That figure shows that many build-up profiles are possible, depending on the assumptions. The base case profile shown is important only because it was the benchmark from which firepower and sustainability comparisons were made with subsequent excursions. The base case and the excursions used are defined below.

THE BASE CASE

In the main text and particularly in Appendix A, we described many of the variables we explored to determine force closure sensitivities. Ultimately, we had to select a set of conditions that, when taken together, constitute a base case delivery profile, which can then be compared with other solutions. Our base case was the best estimate of the set of conditions reflecting conservative assumptions on the availability of airlift and sealift assets necessary for this size deployment. The principal parameters are as follows:

- We assumed that 75 percent of the total Military Airlift Command (MAC) fleet was available for these simulated deployments, instead of either the 100 percent or 50 percent we explored in the sensitivity analysis. We assumed that a force deployment of that size would have sufficient urgency to demand a level of resources higher than 50 percent, but that other demands would keep the committed level below 100 percent.
- We determined that passenger aircraft augmentation was necessary to avoid an undue delay in force closure. We begged the question of whether Civil Reserve Air Fleet Stages I, II, or III would be activated by assuming that we could charter 25 wide-body passenger aircraft after Day 30. At the 75 percent assumed apportionment, and using MAC aircraft for both cargo and passengers, 25 aircraft after Day 30 allowed us to maintain a balance between the cargo and passengers being deployed.
- The Military Sealift Command (MSC) fleet, including the active charters; the afloat pre-positioned ships; and the fast sealift ships (SL-7s), were assumed to be available at Day 2. The entire Ready Reserve Force (RRF) was activated and assumed to be available on the planned 5-, 10-, and 20-day schedule. Augmentation of the MSC fleet and RRF ships was necessary, primarily to move supplies and ammunition and was accomplished by assuming ships from the U.S. flag fleet were available for loading after Day 15.
- Initial airlift priority was given to the Air Force tactical fighter squadrons.
- Airborne division was given first priority within the Army and was moved by air.
- SL-7s were designated to carry two active brigades of a mechanized division, as well as the air assault division, with no support units.
- We made no attempt in the base case to refine the support to combat weight ratios; units flowed in accordance with their Service-assigned required delivery dates (RDDs) and specified modes if applicable. One result was a

very slow support force build-up, which we believed to be an unacceptable solution.

FORCE FIREPOWER BUILD-UP: BASE CASE COMPARED WITH EXCURSIONS

Subsequent excursions from one base case were intended to not only increase the base case firepower build-up but also to solve the perceived shortfall in sustainability reflected by the base case support to combat ratio. While the following three excursions represent only some of the many we examined, they were selected for comparison purposes since they have sufficiently different solutions. We have labeled them Excursion A, B, and C, and the results are illustrated in Figures B-2 through B-6.

- **Excursion A:** The same parameters described for the base case were used, with the following exceptions.
 - ▶ We allowed all cargo, both combat and support, to compete for the SL-7s rather than specify the use of those ships for the mechanized and air assault division.
 - ▶ We used the priority for movement established by the Service-generated RDDs associated with all units and allowed all requirements to compete for all lift without restrictions.

This excursion resulted in an inordinately high support-to-combat ratio and a very slow combat force deployment because support units incrementally require smaller lift packages and will move ahead of larger units in the simulation if the RDD's are the same.

- **Excursion B:** In this excursion, RDDs for the combat force were refined relative to the support force to construct an acceptable support-to-combat weight ratio. The result is a more balanced deployment.
- **Excursion C:** In this excursion, we made the following changes to the base case:
 - ▶ We used the results of our static analysis linking mobility requirements to firepower values to maximize early firepower. Specifically, we did not require the airborne division to move by air and we adjusted the RDDs to allow a mechanized brigade to compete for early airlift.
 - ▶ At the same time, we maintained a balanced allocation of lift between combat and support units.

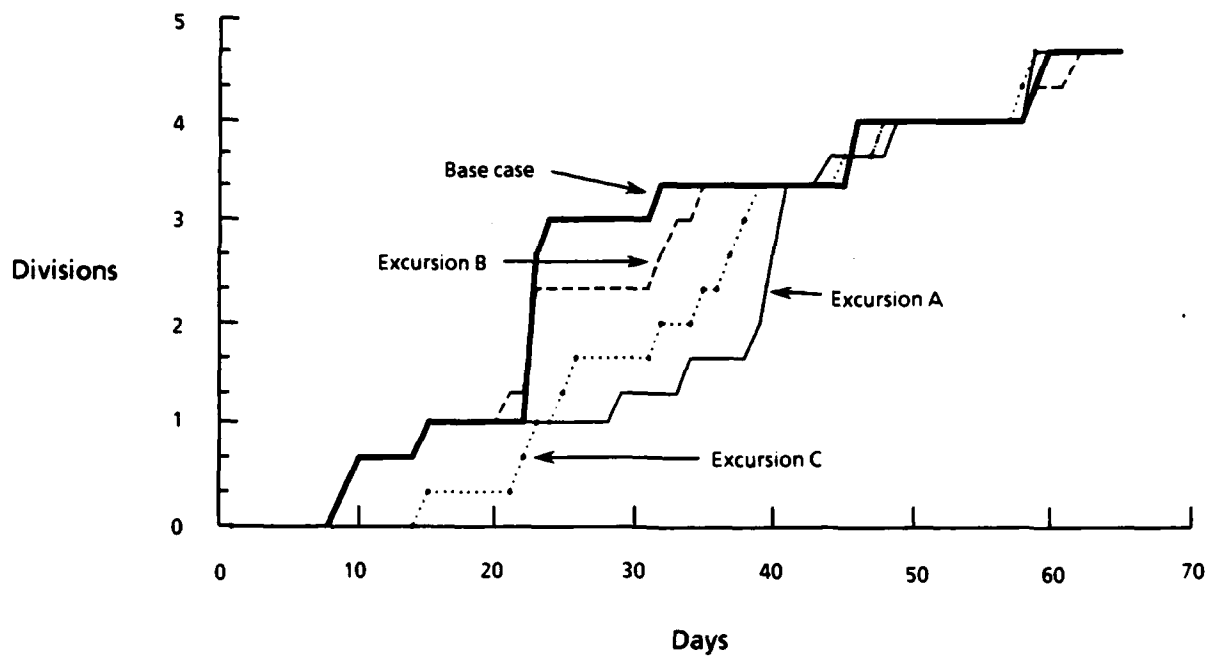


FIG. B-2. DIVISIONAL BUILD-UP COMPARISONS
(Brigade increments)

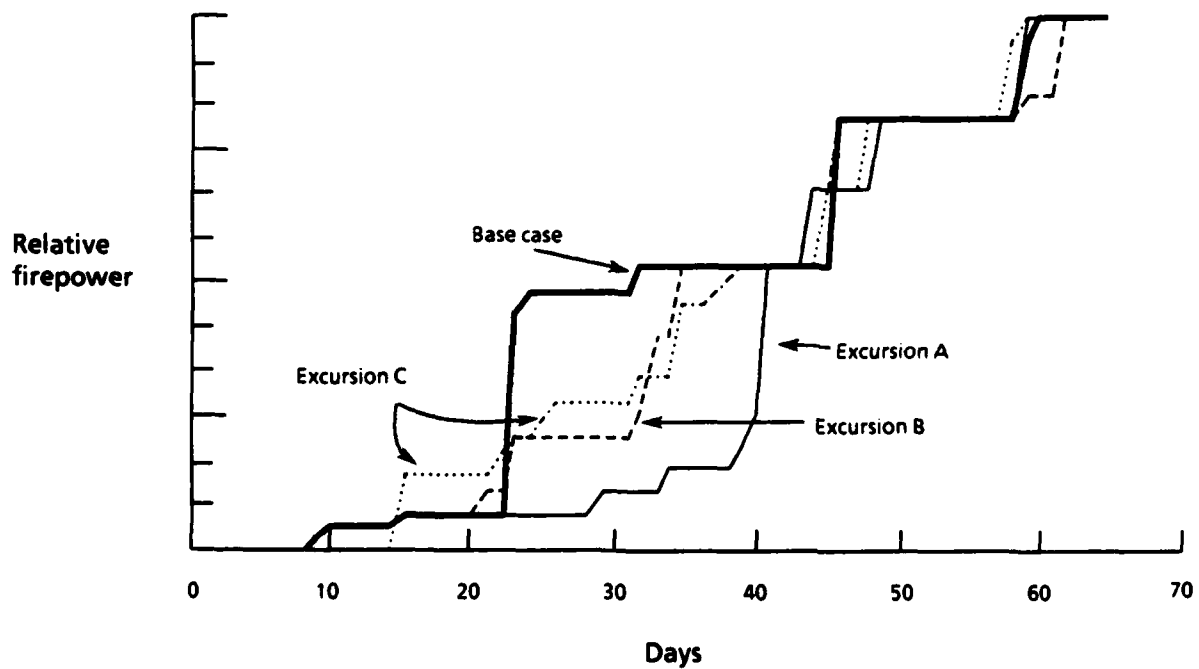


FIG. B-3. DIVISIONAL BUILD-UP COMPARISONS
(Relative firepower)

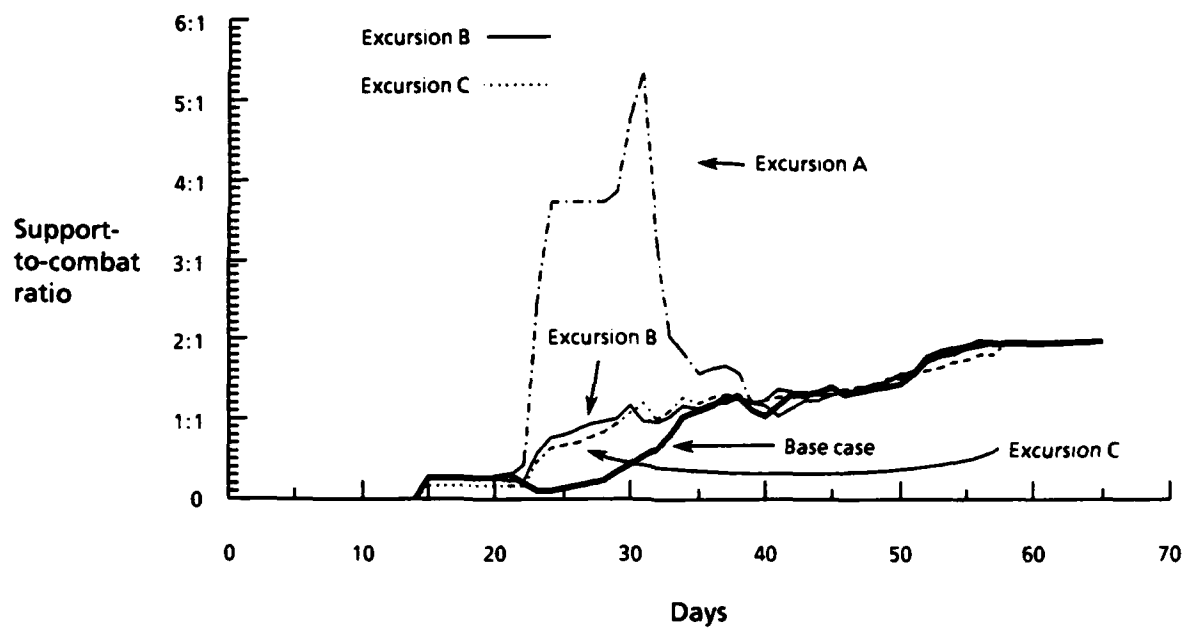


FIG. B-4. SUPPORT-TO-COMBAT RATIO COMPARISON
(Unit equipment tons delivered)

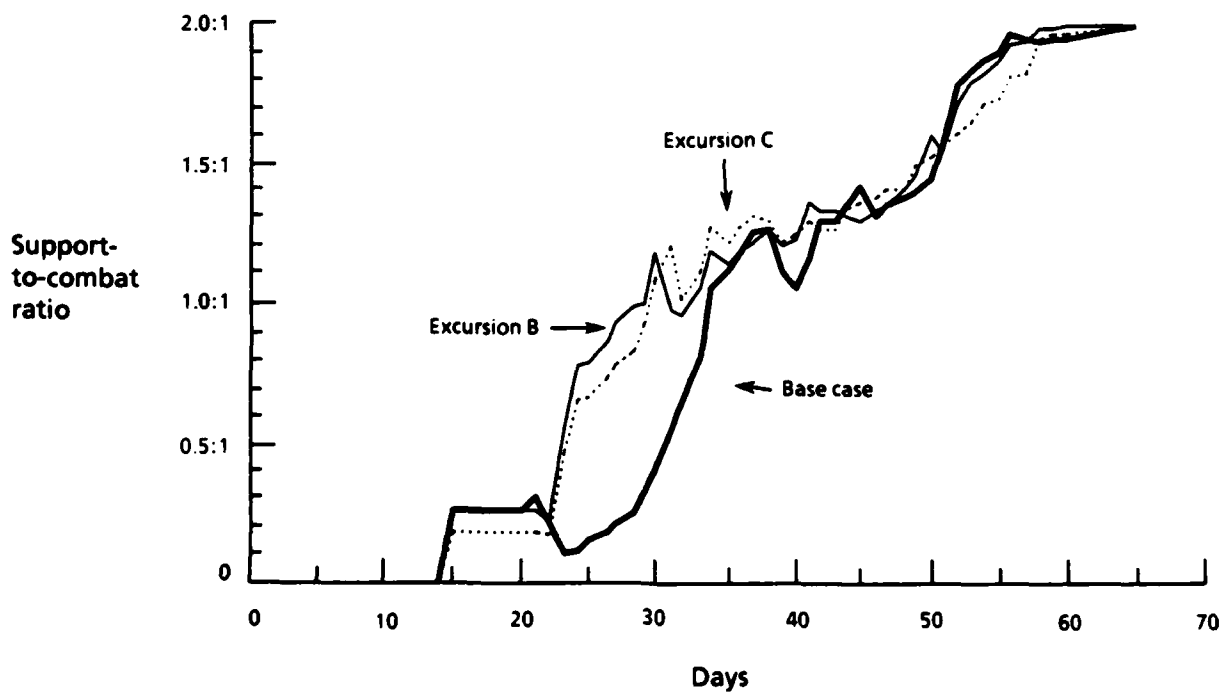


FIG. B-5. SUPPORT-TO-COMBAT RATIO COMPARISON
(Less Excursion A)

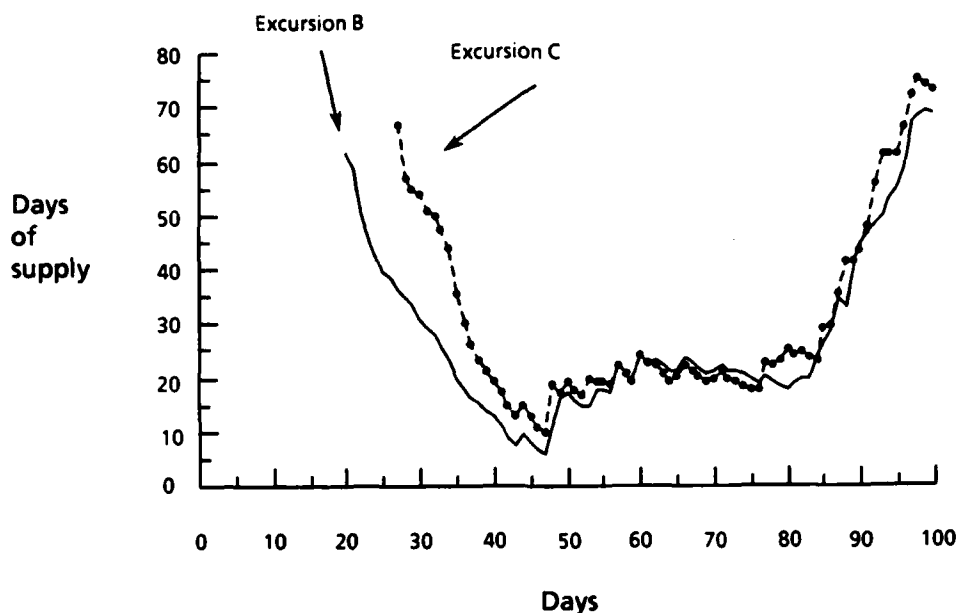


FIG. B-6. DAYS OF DRY CARGO SUPPLY FOR ARMY UNITS DEPLOYED
(Excursions B and C compared)

While the iterative process we used could produce many acceptable solutions, Excursion C is our choice for illustrating that while using the same available lift, it is possible to increase firepower and at the same time maintain a balance between combat and support. In Chapter 2, we illustrated the problem of trying to link the three elements of our analysis: mobility, sustainability, and firepower. Some of the figures used in those illustrations are included in the following sets, with labels and a more detailed explanation of the data differences in the four cases we chose for discussion.

BRIGADE BUILD-UP

One measure of incremental combat force deployed is the number of divisional maneuver brigades. Figure B-2 shows the division build-up curves in our base case and excursions. From the number of divisions deployed, subdivided by brigade increment, it appears that the base case and Excursion B represent the more favorable deployments and Excursions A and C the least favorable. The reason the base case and Excursion B appear similar in numbers of brigades is that the early airlift was devoted to the airborne division and the early sealift to the mechanized

and air assault divisions. Excursion A utilized the fast sealift ships to move support units rather than the dedicated combat units as in the base case, and the result is evident in Figure B-2. In Excursion C, we gave some of the early airlift to a mechanized brigade, slowing down the closure of the first complete brigade-sized element. As the airlift necessary to move personnel is reallocated between all claimants, other differences among the cases appear. Figure B-2 shows only the combat brigades; lift is used for many other claimants that are not shown in the figure, such as Air Force requirements and Army and Marine Corps support requirements.

Because all brigades are counted equally here, whether they are an Army airborne or mechanized brigade or a Marine Expeditionary Brigade, we think firepower buildup shown in Figure B-3, is a better way to evaluate force build-ups.

FIREPOWER BUILD-UP

A different picture is presented when we use firepower rather than number of units as the measure of effectiveness. Figure B-3 shows that while the Excursion C build-up is slower (as seen in Figure B-2), the firepower associated with the heavy brigades is far greater than that associated with the brigades that arrive earlier in the base case. Excursions A and B do not appear to offer competitive solutions. The comparison of Figures B-2 and B-3 shows that a clear trade-off is evident between the base case and Excursion C; in the base case, we deploy a division-size force by Day 15, while in Excursion C we deliver only a brigade by the same time day. However, the brigade delivered in Excursion C has twice the firepower of the division deployed early in the base case.

The base case still displays a potent firepower build-up with the arrival of the fast sealift ships on Day 23. Additional excursions could seek to further refine the use of lift by moving one mechanized brigade by air, as in Excursion C, and another by fast sealift, as in the base case. The complicating factor is how the premium mobility assets (air and fast sealift) are allocated to support units.

SUPPORT-TO-COMBAT WEIGHT RATIOS

The sustainability issue is an additional dimension that must be considered before a judgment can be made as to which of the four cases represents the better deployment. The first sustainability measure of effectiveness to compare is the

amount of combat service support unit equipment deployed with the combat force, shown as a ratio. Figure B-4 shows the support-to-combat ratio for each of the four cases we have discussed. Two cases stand out: Excursion A, with a spike in the ratio which exceeds 5:1 at Day 31, and the base case, which approaches 0.1:1 at Day 23. From the logistics perspective, neither of these solutions is acceptable. The ratios seen in the base case result from combat unit tonnages receiving priority for lift assets; with support ratios that low, the force is not sustainable. In Excursion A, the combat and support competed for the available lift in accordance with their assigned RDDs to correct the base case support imbalance, but as seen in Figures A-2 and A-3, the cost was an inordinate delay in combat force arrivals. If the support-to-combat ratios are compared with either the force or firepower build-up rates, it is apparent that the support ratio is inversely related to the force and firepower build-up rates in the base case and Excursion A: as combat power goes up, the support ratio goes down. The key is to find the right balance among all indicators.

Because the combat force deployment in Excursion A was inordinately slow and the support-to-combat ratio was inordinately high, we rejected that alternative as a viable solution. Figure B-5 shows the remaining three cases on an expanded scale, which gives a clearer delineation of the differences between Excursions B and C. From a supportability perspective, either of these solutions is acceptable. The judgment as to which is better must be made by joint consideration of the combat force build-up and the support-to-combat ratio. Having now reduced our choices to Excursion B or Excursion C, the only remaining question is which measure of effectiveness should be used. As we saw, Figure B-2 shows numbers of divisions at brigade level increments and favors Excursion B, and Figure B-3 shows firepower build-up and favors Excursion C.

One final check is possible to help resolve the choice. Since we know that the deployment sequence affects the amount of consumption over time, we can examine the difference in net stockage position between Excursions B and C, as shown in Figure B-6. Accepting that the calculation of consumption is far more complicated than the following illustrations presume (i.e., ammunition consumption varies for different types of units, intensities and the start of hostilities are driven by scenario assumptions, etc.), we can still make the point by using theater average consumption rates (excluding ammunition) and display the effect on theater stocks caused by the deployment sequence alone.

Since Excursion B has a more rapid deployment of forces than Excursion C (albeit one with less firepower), the consumption of pre-positioned stocks begins earlier, they are drawn down at a faster rate, and they bottom out at a lower point before replenishment stocks arrive in sufficient quantity to meet consumption and rebuild the stockpile. Thus, even though the support-to-combat ratio is similar between Excursion B and Excursion C, the days-of-supply picture presented by Excursion C is preferable to that of Excursion B. That fact, in combination with the superior firepower build-up in Excursion C, leads us to conclude that it is the best choice of the four we have discussed.

These cases comparing support-to-combat ratios reflect differences in sequencing Army units. The same problem with sustainability does not occur with Marine units if they are deployed as part of either an amphibious task force or an Maritime Prepositioned Ship (MPS) brigade. For those configurations, the support units and supplies are an integral part of the combat force, and lift decisions are much simpler.

GENERAL COMMENTS

We know that no decision on force selection or sequencing could be made solely on the considerations we have presented here. We also know that the actual behavior of variables such as consumption over time is far more complex than we have made it seem. Still, the examples shown illustrate the result of different approaches to force sequencing, among the choices available, recognizing that other factors must be weighed by decision makers in determining which units to deploy and when those units should be deployed in relation to each other. These other factors include operational considerations such as the threat, warning time, unit readiness, the political environment, and others.

Force Structure Decisions

A related question is, "Which units remain in the force and are available to form a time-phased force deployment list"? Decisions will soon be made as to the composition of our forces for the future. Our exemplary deployments led to the selection of Excursion C as the best combination of the use of the available lift, sustainability, and combat power. The deployment sequence in Excursion C gave airlift priority to a mechanized brigade at the expense of an airborne division. While it is true that the heavier unit took longer to deploy, all the deployment sequences

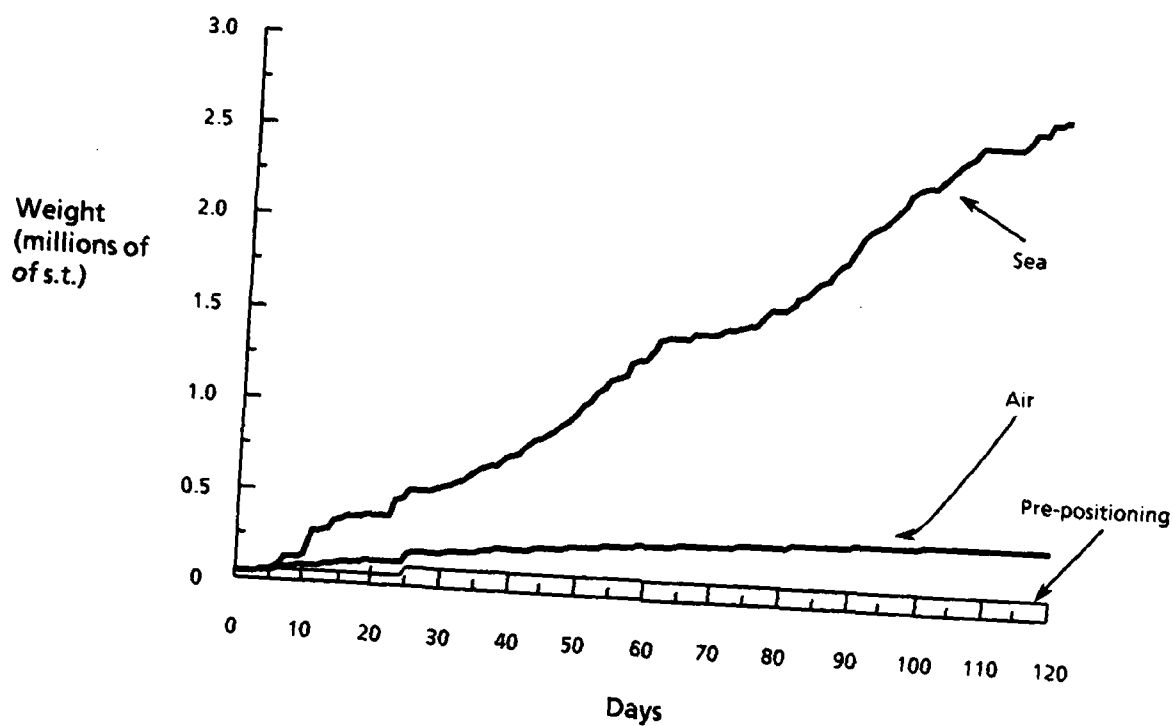
other than Excursion A resulted in the deployment of combat forces with little warfighting capability until well after Day 30. The early deployment of light forces, with little firepower and sustainment capability, potentially *increases* the period the units are at risk, perhaps with little operational justification.

Our analysis has shown some quantifiable relationships between mobility, sustainability, and firepower. The utility of the analysis will not be felt unless these relationships are considered in future force structure decisions. The pressure to build more light, easily deployable forces in lieu of the Europe-oriented heavy forces is growing, particularly given the reality of the recent Persian Gulf deployment. However, this analysis and that deployment show we cannot build up enough sustainment capability until the sea line of communication is opened. That analysis and experience led to the conclusion that heavy forces can still be usefully included and, given the number of countries around the world with substantial armored capability, probably will still be required.

Lighter Equipment in the Context of Total Force Requirements

Some parts of the Defense community are already suggesting that lighter armored vehicles that are air transportable make more sense than the M1 tanks and Bradley fighting vehicles we currently employ. The decision to convert our forces to a new family of armored vehicles may well be justified. But it ought to be justified for reasons other than the fact that they are air transportable. The reason is best displayed in Figure B-7.

The five-division force we moved to the Middle East in our simulations required the movement of almost 2.8 million tons of unit equipment and supplies. Three basic means are available to provide the necessary equipment and supplies: pre-positioning, airlift, and sealift. Each has an important role that complements the others, but from the relative contributions, we clearly see that no sustainable force of any substantial size would ever be able to deploy solely by air. Force structure and equipment-related decisions that are intended to lighten a force are often made without considering the total movement requirement. While a mechanized unit equipped with lighter armor, for example, could be airlifted with fewer aircraft and thus deployed more quickly, considering the limited role airlift plays in a total deployment (Figure B-7), the effect on force employability would only be marginal.



Note: s.t. = short tons.

FIG. B-7. BASE CASE DELIVERIES BY MODE

Yet the sacrifice in combat capability could be substantial, and it may not be worth the marginal improvement in mobility.

Mobility Implications

If force structure decisions are going to be made with the mobility implications considered, then the entire range of mobility options need to be considered and not just air transportability. This point does not diminish the critical contributions that airlift makes in a deployment. The issue is how do we best use all the mobility resources potentially available? Pre-positioning is an option that can overcome the limitations of both airlift and sealift, but it has limitations of its own. Maritime pre-positioning of Army equipment, similar to the Marine Corps MPS sets, may be a less-expensive and more-easily-deployed option. The changing nature of our responsibilities in NATO could allow much of the prepositioning of materiel configured to unit sets (POMCUS) equipment to be redistributed. Sealift will continue to play the predominant role in our deployability, and many improvements are possible in that area. Recognition that our power projection depends on sealift

will force us to address sealift improvement realistically. Focusing on air transportability alone does not solve the problem: from the perspectives we have explored in this paper, any force structure decision to lighten forces to improve our deployability is a movement in the right direction only if the firepower and sustainability characteristics of the resulting force meet contingency requirements.